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THE DEVELOPMENT OF A NEW METHOD OF RESEARCH.*

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IN the fruitful field of astrophysical research there are few opportunities for advance so promising as those afforded by the study of the sun. As the central body of the solar system, maintaining the planets in their orbits by the power of its attraction, and supplying light and heat to the inhabitants of the earth through its radiation, the sun is an object of special interest to every student of nature. Its appeal to the imagination may be said to be threefold in character. In the first place, because of the extraordinary nature of the phenomena on its surface, and the stupendous scale of the eruptive disturbances, which are becoming more and more frequent in the present period of solar activity, the study of the sun for the purpose of gaining an understanding of its structure is in itself a sufficiently attractive object. To some, however, whose interests are aroused more particularly by the problems of chemistry and physics than by those of astronomy, this aspect of solar research may not possess special interest. But through the development of astrophysical methods, it is precisely to the physicist and the chemist that the sun should make a special appeal. For the solar observer may be the spectator of physical and chemical experiments on a scale far transcending any that can ever be performed in the laboratory. In this enormous crucible, heated to temperatures greatly exceeding those attainable by artificial means, immense masses of luminous vapor, including most of the elements known on the earth and many not yet discovered here, may be seen

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undergoing changes and transformations well calculated to assist in the explanation of problems which the laboratory can not solve.

But to the philosopher and the student of nature as a whole, the sun finds its highest interest in its relationship to the great problem of stellar evolution. For the central body of our system is a star, resembling in the closest way many of the stars of the sidereal universe, but possessing the unique distinction of comparative proximity to the earth. Even in the most powerful telescopes, all the other stars appear as minute points of light, which every improvement in telescope construction tends to render more minute and microscopic, so great is the distance of these stars from the observer on the earth. We have no reason to believe that telescopes will ever be constructed so powerful as to magnify a stellar image into an actual disk. With our present knowledge we therefore may not expect that the great flames and other evidences of eruptive phenomena, which we believe from inference to be as characteristic of the stars as of the sun, will ever become visible. We must therefore depend for a knowledge of such phenomena upon the one star whose surface can be studied in detail. Armed with this knowledge, we may trace out with the spectroscope successive steps in the development of a star, from its origin in a nebula, on through the earlier stages typified by such stars as Sirius, to the condition attained in the sun. In this object we seem to observe the culmination of stellar life. For evidences of decay we must investigate the red stars, in which the radiation of heat throughout immense periods of time has resulted in cooling toward the point of final extinction. Thus we may untangle the great problem of stellar evolution, and at the same time build up a complete history of the sun, learning what it has been, what it is and what it will become.

Prior to the middle of the nineteenth century, at periods of total eclipse, when the dark body of the moon cuts off completely the bright light of the solar disk, red flames were observed at many points on the moon's circumference. At first their nature was so little understood that they were described by some observers as lunar mountains. But in 1868, through the use of the spectroscope, their true gaseous nature and their connection with the sun became known. It was found that immense masses of hydrogen and helium gas rise from a sea of flame (the chromosphere) which completely envelops the sun, and that these 'prominences' sometimes attain elevations of hundreds of thousands of miles.

The rarity and brief duration of total eclipses would have limited greatly our knowledge of the prominences, had not a method been devised by which they can be observed on any clear day in spite of the glare of our atmosphere around the sun. The instrument which permits this result to be accomplished is the spectroscope, used in con-

junction with the telescope. The principle of the method is simple and easily understood. The white light of the sky, when passed through a spectroscope, is drawn out into a long rainbow band, and thereby enormously reduced in intensity. The light of the prominences, on the contrary, is concentrated in the radiations characteristic of hydrogen and helium gas, and the great dispersing power of the spectroscope merely separates more and more widely the colored images which correspond to these radiations, without greatly reducing their intensity. With the spectroscope they therefore become visible, since their images are brighter than the highly dispersed background of skylight on which they lie.

Armed with this method, observers in various parts of the world have systematically observed the forms of the solar flames on every clear day, giving us a continuous record of these phenomena now extending back for more than thirty years. From a study of this record many conclusions regarding the nature of the flames and their bearing on the question of the solar constitution, have already been reached. But the process of observation is not only slow and painstaking; it is also subject to the errors and uncertainties that attend the hand delineation of every object, seen through a fluctuating atmosphere, under unfavorable conditions. It was principally in the hope of simplifying this process, and of rendering it more rapid and more accurate, that the spectroheliograph was devised by the writer in 1889.

The principle of this instrument is very simple. Its object is to build up on a photographic plate a picture of the solar flames, by recording side by side images of the bright spectral lines which characterize the luminous gases. To accomplish this an image of the sun is formed by the telescope on the slit of a spectroscope. The light of the sun, after transmission through the spectroscope, is spread out into a long band of color, crossed by lines representing the various elements. At points where the slit of the spectroscope extends out beyond the sun's edge across a gaseous prominence, the bright lines of hydrogen and helium may be seen extending from the base of the prominence to its highest point. If a series of images of such a line, corresponding to different positions of the slit on the prominence, were recorded side by side on a photographic plate, it is obvious that they would give a representation of the form of the prominence itself. To produce such an effect it is only necessary to cause the solar image to move at a uniform rate across the first slit of the spectroscope and then, with the aid of a second slit, which takes the place of the eyepiece of the spectroscope, to isolate one of the lines, permitting the light from this line, and from no other portion of the spectrum, to pass through the second slit to a photographic plate. If the plate is moved at the speed with which the solar image passes across the

first slit, an image of the prominence will be recorded upon the plate. The principle of the instrument thus lies in photographing the solar

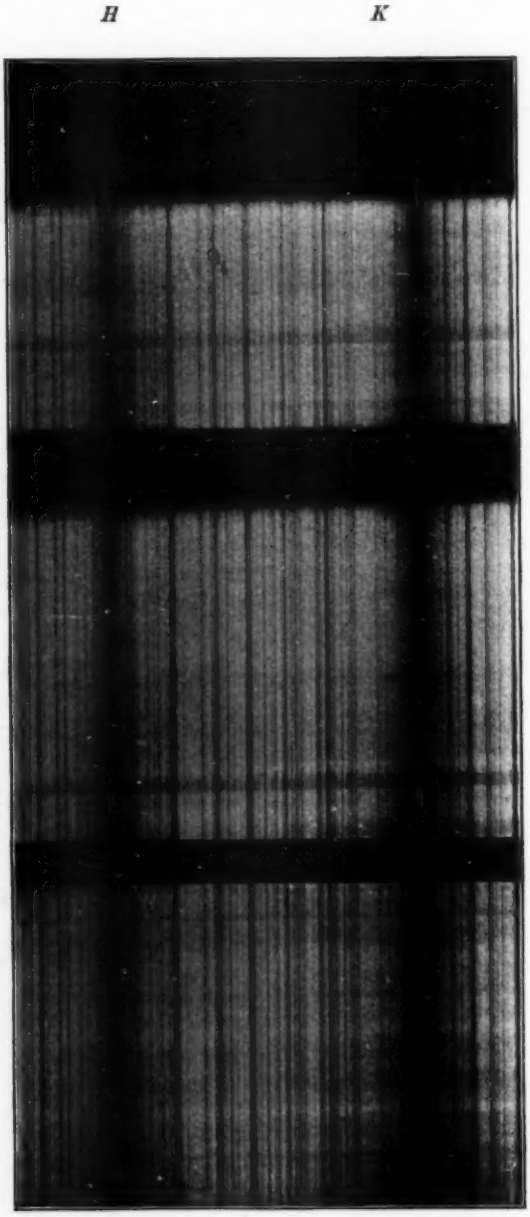


FIG. 1. — *H* AND *K* LINES ON THE DISK, IN THE CHROMOSPHERE, AND IN A PROMINENCE (*a*).

flame through a narrow slit, from which all light is excluded except that which is characteristic of the prominence itself.

This method, when tried by the writer at the Harvard Observatory in 1890, proved unsuccessful. The lack of success was partly due to the fact that a line of hydrogen was employed. This line, though fairly suitable for the photography of prominences with the perfected spectroheliograph of the present day, was too faint for successful use

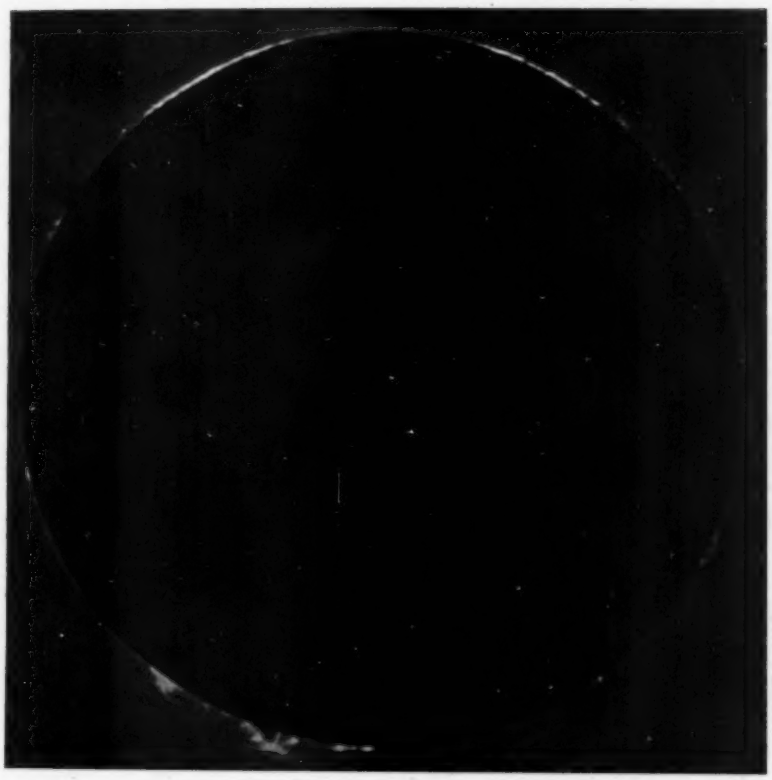


FIG. 2. THE SOLAR CHROMOSPHERE AND PROMINENCES.

amidst the difficulties which surrounded the first experiments. Accordingly, when the work was resumed a year later at the Kenwood Observatory in Chicago, an attempt was first made, through a photographic investigation of the violet and ultra-violet regions of the prominence spectrum, to discover other lines better fitted for future experiments. In the extreme violet region, in the midst of two broad dark bands which form the most striking feature of the solar spectrum, two bright lines (H and K) were found which were attributed to the vapor of calcium. They had previously been seen visually in the prominences, but on account of the insensitiveness of the eye for light of this color, their true importance had hardly been realized. A careful study soon showed them to be present in every prominence observed, at eleva-

tions above the solar surface equaling or exceeding those attained by hydrogen itself (Fig. 1, *a*). Their suitability for the purpose of prominence photography is due to several causes, among which may be mentioned their great brilliancy, their presence at the center of broad dark bands which greatly diminish the brightness of the sky spectrum, and the comparatively high sensitiveness of photographic plates for light of this color.

While fairly efficient from an optical point of view, the spectroheliograph of the preceding year had possessed many mechanical defects. In a new instrument, devised for use with the twelve-inch Kenwood telescope, these were overcome, and means of securing the necessary conditions of the experiment were provided. The first trials

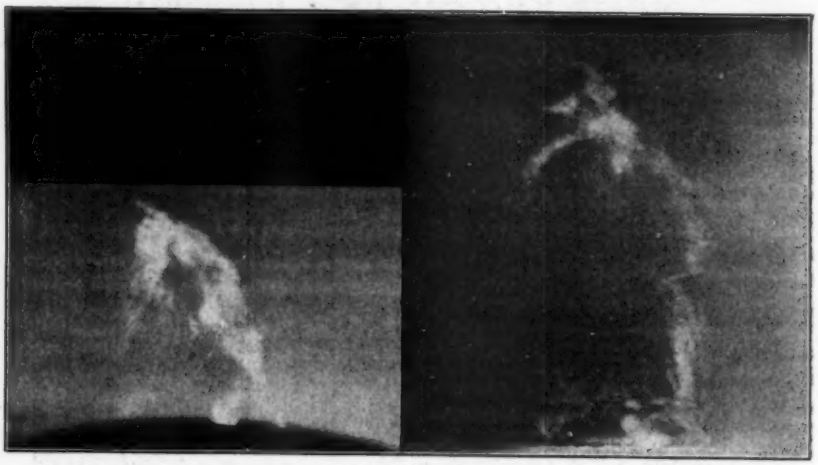


FIG. 3. ERUPTIVE PROMINENCE OF MARCH 25, 1895. *a*, 10^h 34^m. HEIGHT, 135,000 MILES. *b*, 10^h 58^m. HEIGHT, 281,000 MILES.

of the instrument, made in January, 1892, were entirely successful, and the chromosphere and prominences surrounding the sun's disk were easily and rapidly recorded (Fig. 2). The details of their structure were shown with the sharpness and precision characteristic of the best eclipse photographs. And the opportunity for making such records, previously limited to the brief duration, never exceeding seven minutes, of a total solar eclipse, was at once indefinitely extended. Thus it became possible to study photographically the slowly varying forms of the quiescent, cloud-like prominences, and, to particular advantage, the rapid changes of such a violent eruption as is illustrated in Fig. 3.

But even before this primary purpose of the work had been accomplished, the possibility of making another and much more important application of the instrument had presented itself. A photographic

study of the spectrum of various portions of the sun's surface had shown the existence at many points of great regions of calcium vapor, luminous enough to render their existence evident through the production of bright *H* and *K* lines on the solar disk (Fig. 1, *b* and *c*). Some of these calcium regions had indeed been known to exist through the visual observations of Professor Young, who had observed the bright lines in the vicinity of sun-spots. But the vast extent of the calcium regions, and the characteristic forms of the phenomena, could not be ascertained by such means. What was required was such a

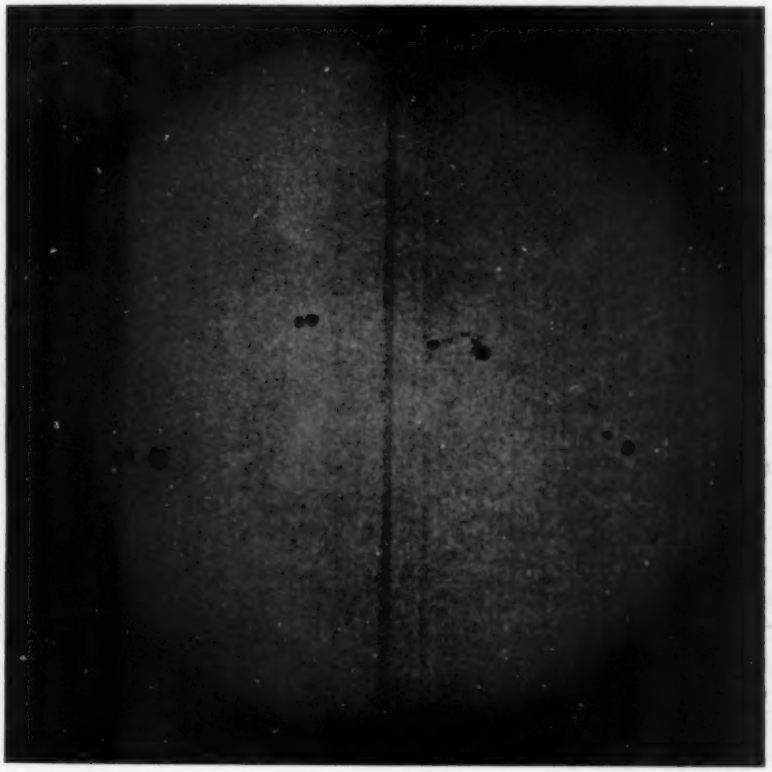


FIG. 4. ORDINARY PHOTOGRAPH OF THE SUN.

representation of the solar disk as the spectroheliograph had been designed to give in the case of the prominences. From a consideration of the results obtained in the spectroscopic study of the disk, it appeared probable that an important application of the spectroheliograph might be made in this new direction.

Before describing this second application of the instrument, it may be well to call attention to the appearance of the sun when seen with a telescope, or when photographed in the ordinary manner, without a

spectroheliograph. Such a photograph is reproduced in Fig. 4. Its most conspicuous features are the numerous dark spots scattered over the sun's surface; these are the well known sun-spots. Near the edge of the sun there may be seen certain bright regions, which are known as faculæ. The calcium regions above referred to are usually associated with the faculæ, but they lie above them, and they give no trace of their existence on ordinary photographs, like the one in Fig. 4, or to the eye when observing the sun through a telescope.

The results of the first experiments, which were made at the beginning of 1892, were such as to justify fully the expectations that had been entertained. It was at once found possible to record the forms, not only of the brilliant clouds of calcium vapor associated with the faculæ, and occurring in the vicinity of sun-spots, but also of a reticulated structure extending over the entire surface of the sun. The earliest applications of the method were made in the study of the great sun-spot of February, 1892, which, through the great scale of the phenomena it exhibited, and the rapid changes that resulted from its exceptional activity, afforded the very conditions required to bring out the peculiar advantages of the spectroheliograph. In the systematic use of the instrument continued at the Kenwood Observatory through the following years, a great variety of solar phenomena were recorded, and the changes which they underwent from day to day—sometimes, in the more violent eruptions, from minute to minute—were registered in permanent form for careful study. During this period, which ended with the transfer of the Kenwood instruments to the Yerkes Observatory, over 3,000 photographs of solar phenomena were secured. From a systematic study of these negatives, in the course of which the heliographic latitude and longitude of the calcium regions in many parts of the sun's disk were measured from day to day, a new determination of the rate of the solar rotation in various latitudes has been made. This shows that the calcium regions, like the sun-spots, complete a rotation in much shorter time at the solar equator than at points nearer the poles. In other words, the sun does not rotate as a solid body would do, but rather like a ball of vapor, subject to laws which are not yet understood.

In this first period of its career the spectroheliograph had therefore permitted the accomplishment of two principal objects. It had provided a simple and accurate means of photographing the solar prominences in full sunlight, which gave results hardly inferior to those obtained during the brief moments of a total eclipse. It had also given a means of recording a new class of phenomena, known previously to exist only through glimpses of the bright calcium lines in the vicinity of sun-spots, but wholly invisible to observation either visually or on photographs taken by ordinary methods. It was not difficult to see, how-

ever, that the possibilities of the new method were much greater than had been indicated by the work so far accomplished. It seemed certain that our knowledge of the finer details of the calcium clouds would be greatly increased if provision could be made for photographing a much larger solar image with a spectroheliograph of improved design. And

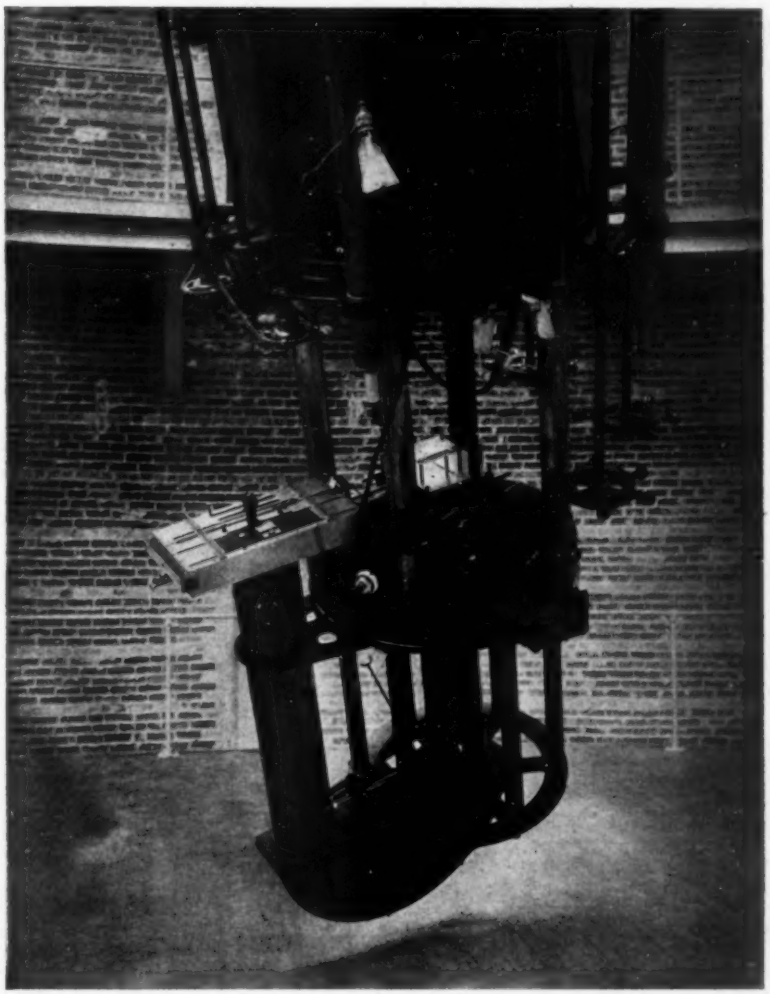


FIG. 5.—THE RUMFORD SPECTROHELIOGRAPH ATTACHED TO THE YERKES TELESCOPE.

it was furthermore evident that other applications of the instrument, involving the use of different spectral lines, and the employment of principles which had not entered in the Kenwood work, might reasonably be hoped for.

The construction of the great forty-inch telescope of the Yerkes

Observatory provided the first requirement of this new work, namely, a large solar image, having a diameter of seven inches as compared with the two-inch image given by the Kenwood telescope. The construction of a spectroheliograph large enough to photograph such an image of the sun involved serious difficulties, but these were finally overcome. The Rumford spectroheliograph, designed to meet the special conditions of the new work, was constructed in the instrument

FIG. 6.—THE SUN SHOWING THE CALCIUM FLOCCULI (H_2 LEVEL). 1903, AUGUST 12, 8h 52m. C.S.T.

shop of the Yerkes Observatory, and is now in daily use with the forty-inch telescope (Fig. 5).

In this instrument the solar image is caused to move across the first slit by means of an electric motor, which gives the entire telescope a slow and uniform motion in declination. The sun's light, after passing through the first slit, is rendered parallel by a large lens at the lower end of the collimator tube. The parallel rays from this lens fall upon a silvered glass mirror, from which they are reflected to the first of two prisms, by which they are dispersed into a spectrum.

After passing through the prisms, the light, which has now been deflected through an angle of 180°, falls upon a second large lens at the

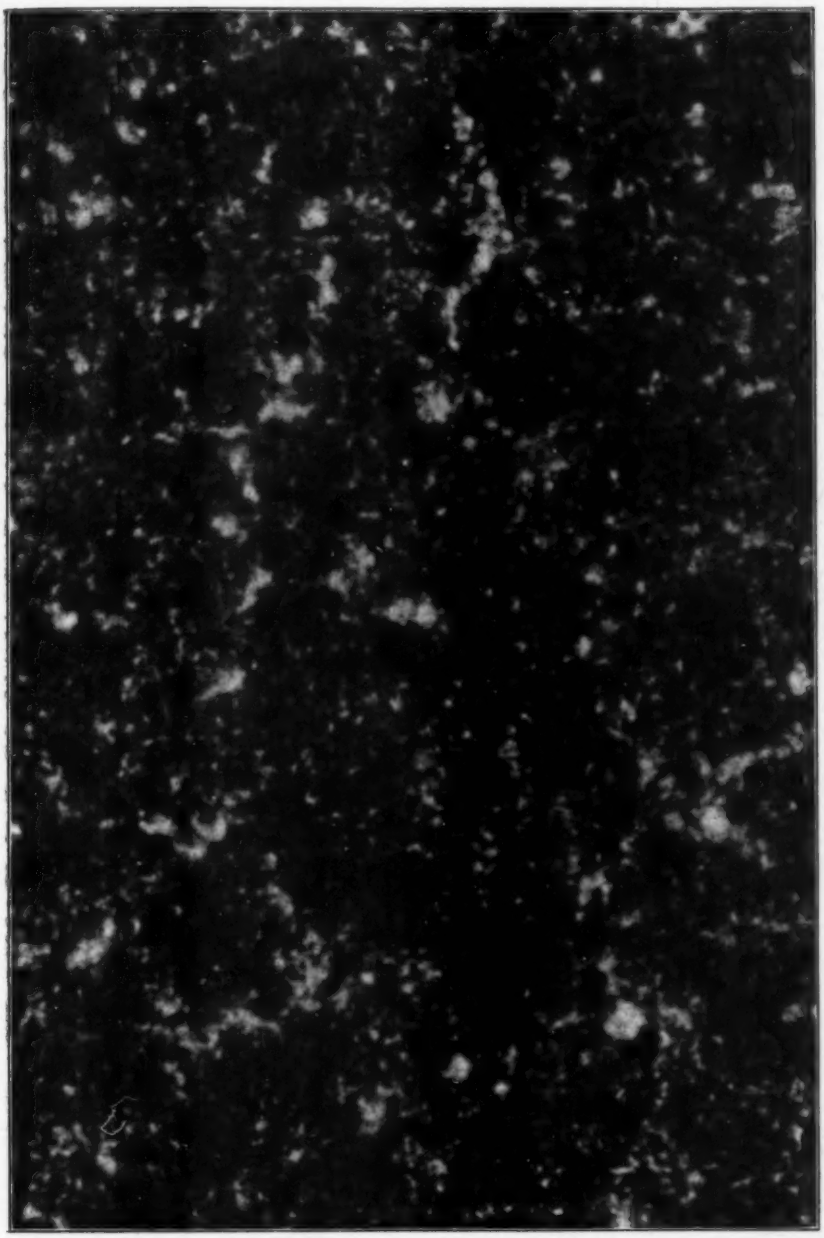


FIG. 7.—MINUTE STRUCTURE OF THE CALCIUM FLOCCULI AT H_2 LEVEL. 1903, SEPTEMBER 22. (Scale: Sun's Diameter = 0.690 Meter.)

lower end of the camera tube. This forms an image of the spectrum at the upper end of the tube, where the second slit is placed. Any line in

the spectrum may be made to fall upon this slit by properly adjusting the mirror and prisms. Above the slit, and nearly in contact with it, the photographic plate is mounted in a carriage which runs on tracks at right angles to the length of the slit. The tracks are covered by a light-tight camera box, so that no light can reach the plate except that which passes through the second slit. While the solar image is moving across the first slit, the plate is moved at the same rate across the second slit, by a shaft leading down the tube from the electric motor, and connected, by means of belting, with screws that drive the plate-carriage.

Photographs of the solar disk taken with this instrument under good atmospheric conditions show a multiplicity of fine details of which no trace appears on the Kenwood plates (Fig. 6). The entire surface of the sun is shown by these plates to be dotted over with minute luminous clouds of calcium vapor, separated by dark spaces, and closely resembling in appearance the well-known granulation of the solar photosphere (Fig. 7). A sharp distinction must, however, be drawn between this appearance, which is wholly invisible to the eye at the telescope, and the granulation of the photosphere. In accordance with Langley's view the grains into which the surface of the sun is resolved under good conditions of visual observation are the extremities of columns of vapor rising from the sun's interior. They seem to mark the regions at which convection currents, proceeding from within the sun, bring up highly heated vapors to a height where the temperature becomes low enough to permit them to condense. It might be anticipated that out of the summits of these condensed columns, other vapors, less easily condensed, might continue to rise, and that the granulated appearance obtained with the spectroheliograph may represent the calcium clouds at the summits of these columns. We might indeed go a step further, and imagine the larger and higher calcium clouds to be constituted of similar vaporous columns, passing upward through the chromosphere and perhaps at times extending into the prominences themselves. But without a means of research now to be described, which represents another application of the spectroheliograph, involving a new principle, the true nature of these phenomena could not be ascertained.

Mention has already been made of the luminous faculæ, which are simply regions in the photosphere that rise above the ordinary level. At the edge of the sun their summits lie above the lower and denser part of that absorbing atmosphere which so greatly reduces the sun's light near the limb, and in this region the faculæ may be seen visually. At times they may be traced to considerable distances from the sun's limb, but as a rule they are inconspicuous or wholly invisible toward the central part of the solar disk. The Kenwood experiments had shown

that the calcium vapor usually coincides closely in form and position with the faculæ, and hence the calcium clouds were long spoken of under this name. In the new work at the Yerkes Observatory the distinction between the calcium clouds and the underlying faculæ is so marked that a distinctive name for the vaporous clouds has become necessary. They have therefore been designated *flocculi*, a name chosen without reference to their actual nature, but suggested by the flocculent appearance of the photographs.

In order to analyze these flocculi and to determine their true structure, a method was desired which would permit sections of them at different heights above the photosphere to be cut off, as it were, and

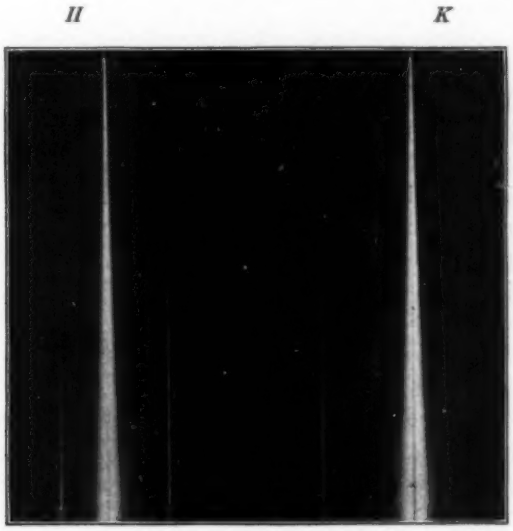


FIG. 8.—*H* AND *K* LINES IN ELECTRIC ARC, SHOWING REVERSALS.

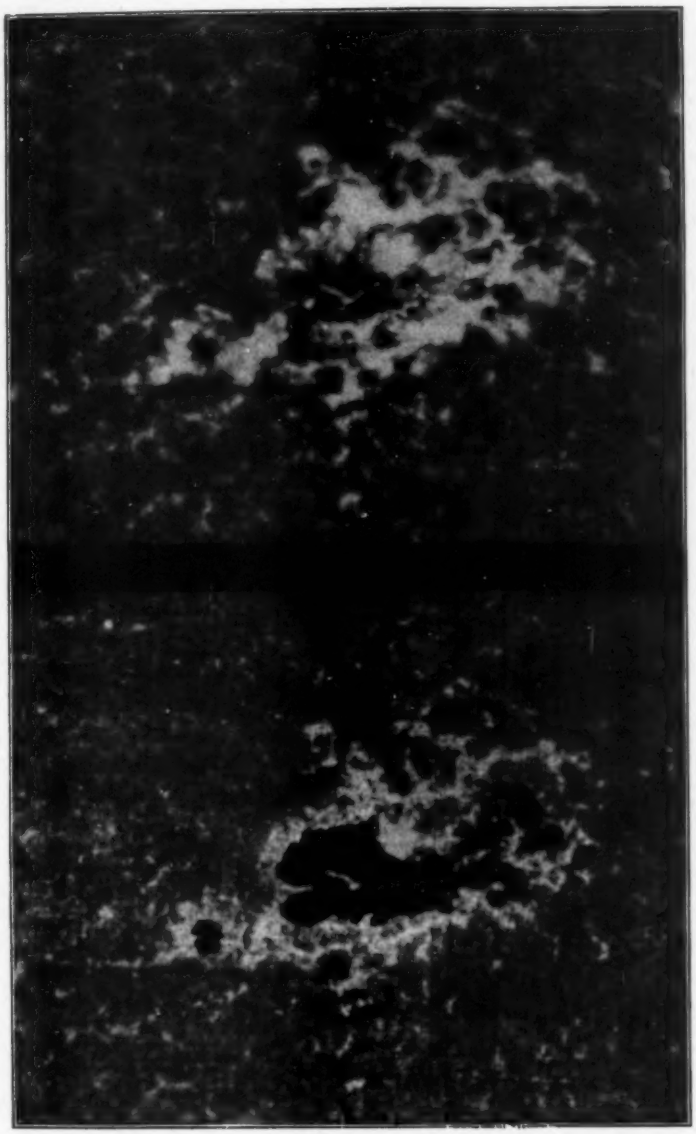
photographed. Fortunately there is a simple means of accomplishing this apparently difficult object. At the base of the flocculi the calcium vapor, just rising from the sun's interior, is comparatively dense. As it passes upward through the flocculi it reaches a region of much lower pressure, and during the ascent it might be expected to expand and therefore to become less dense. Now we know from experiments in the laboratory that dense calcium vapor produces very broad spectral bands, and that as the density of the vapor is decreased these bands narrow down into fine sharp lines (Fig. 8). An examination of the solar spectrum will show that the *H* and *K* lines of calcium give evidence of the occurrence of this substance under widely different densities in the sun. The broad dark bands, which for convenience we designate as H_1 and K_1, are due to the low-lying dense calcium vapor (Fig. 1). At their middle points (over flocculi) are seen two bright

lines, which are much narrower and better defined. These lines, which we designate as H_2 and K_2, are the ones habitually employed in photographing the flocculi with the spectroheliograph. Superposed upon these bright lines are still narrower dark lines, due to the absorption of cooler calcium vapor at higher elevations (H_3, K_3). It will be seen that the evidence of the existence of calcium vapor at various densities in the sun is complete, and that we may here find a way of photographing the vapor at low levels without admitting to the photographic plate any light that comes from the rarer vapors at higher levels. It is simply necessary to set the second slit of the spectroheliograph near the edge of the broad H_1 or K_1 bands, in order to obtain a picture showing only that vapor which is dense enough to produce a band of width sufficient to reach this position of the slit. No light from the rarer vapors above can enter the second slit under these circumstances, since they are incapable of producing a band of the necessary breadth. Light from the denser vapors below will, however, enter the slit. But since it happens, within certain limits, that the vapor grows brighter and also expands as it rises above the photosphere, it seems to follow that a photograph will generally represent a section of the vapor at the level corresponding to the position of the line on the slit, and that little confusion will result from the presence of the denser but less brilliant vapors lying below.

The great sun-spot of October, 1903, afforded an opportunity to try this method in a very satisfactory manner. Sections of the calcium vapor in the neighborhood of this spot-group, corresponding to the two different levels photographed on October 9, are shown in Fig. 9.* The manner in which the vapor at the H_2 level overhangs the edge of the sun-spot is very striking, and thorough study should throw some light on the conditions which exist in such regions. For it is possible, not only to photograph sections of the vapor at various levels, but also to ascertain by the displacement of the H_2 line, as photographed with a powerful spectroscope, the direction and velocity of motion of the vapor which constitutes the flocculus. It is commonly found that the vapor is moving upward at a velocity of about one kilometer per second, though the velocity varies considerably at different

* Although these photographs have been arranged for comparison with the stereoscope, it is to be understood that no stereoscopic effect in the ordinary sense will be obtained in examining them. The purpose of using the stereoscope is simply to allow the images to be superposed, thus permitting them to be seen at the same point in rapid succession by simply moving a card so as to cover alternately the two lenses of the stereoscope. In this way the sun-spot may be examined, first as it appears at the low level of the denser vapor and then as it appears at the higher level of the rarer vapor. Thus the manner in which the calcium flocculi overhang the penumbra, and sometimes the umbra, of spots can be observed.

points and under different conditions. In the near future it is proposed to make a careful systematic study of the motion of the vapor at various regions in the flocculi, in order to determine whether it is gen-



Oct. 9, 3h 43m. Calcium Flocculi, Middle H_1 Level. October 9, 3h 30m. Calcium Flocculi, H_2 Level.
Slit at λ 3965. Slit at λ 3968.6.

FIG. 9.—THE GREAT SUN-SPOT OF OCTOBER, 1903.
For Comparison with the Stereoscope (see Footnote on p. 494).

erally upward or whether there may be frequent evidence of downward currents or of currents more nearly parallel to the solar surface.

Many photographs show the existence of flocculi remarkable for their great brilliancy. In these regions active eruptions are in

progress. The vapor, rendered highly luminous by intense heat or other causes, is shot out from the sun's interior with great velocity. Consequently there are rapid changes in the forms of these brilliant regions, whereas the more extensive flocculi, which occupy the greater part of the photograph, change slowly, and represent a much less highly disturbed condition of affairs. The brilliant eruptive flocculi always occur in active regions of the solar surface, and doubtless correspond with the eruptive prominences sometimes photographed projecting from the sun's limb. A remarkable instance was recorded on the Kenwood photographs, which showed four successive stages in an eruption of calcium vapor on an enormous scale. A vast cloud thrown out from the sun's interior completely blotted from view a large sunspot, and spread out in a few minutes so as to cover an area of four hundred millions of square miles.

As already remarked, these eruptive flocculi probably correspond in many instances with the eruptive prominences observed at the sun's edge. But it must not therefore be concluded that the quiescent calcium flocculi correspond with the quiescent, cloud-like prominences. As a matter of fact, we have good evidence for the belief that the flocculi shown in these photographs represent in most instances comparatively low-lying vapors, which, if observed at the sun's edge, would hardly project appreciably above the level of the chromosphere.

In a few cases, represented, perhaps, by the dark calcium flocculi found on certain photographs, the quiescent calcium prominences have been recorded in projection on the disk. But such instances will remain exceptional until a spectroheliograph has been constructed of such high dispersion as to permit photographs to be made with the light of the K_3 line exclusively.

So far we have considered the photography of the sun with the light of the H and K lines of calcium. But it must naturally occur to any one familiar with the solar spectrum that it should be possible to take photographs corresponding to other lines, and thus representing the vapors of other substances. In the solar spectrum some 20,000 lines have been recorded in the great photographic map and catalogue of Rowland, representing almost all the elements known on the earth, and doubtless including many of the radiations of substances which are as yet unknown to terrestrial chemistry. Just as the gas helium was discovered in the sun long before it was found by Ramsay in the laboratory, so we may confidently expect that many other substances represented by lines in the solar spectrum will ultimately be detected on the earth.

Now these lines, like the H_1 and K_1 bands, are dark, and at first sight it might be supposed that for this reason the vapors corresponding with them could not be photographed with the spectroheliograph. But

a moment's consideration will show that no serious difficulty need arise from this cause. For the darkness of the lines is only relative; if they could be seen apart from the bright background of continuous spectrum on which they lie, these lines would shine with great brilliancy. It is thus evident that if all light except that which comes from one of these dark lines can be excluded from the photographic plate by means of the second slit of the spectroheliograph, it should be possible to obtain a photograph showing the distribution of the vapors corresponding with the line in question.

At this point attention should be called to the extreme sensitiveness of the spectroheliograph in recording minute variations in the intensity of a line—variations so slight that no trace of them can be seen in a spectrum photograph showing only the line itself. A well-known physiological action is here concerned, for it is common experience that the eye can not detect minute differences of intensity in various parts of an extremely narrow line, whereas these would become much more conspicuous if the line were widened out into a band of considerable width. The action of the spectroheliograph is to record side by side upon the photographic plate a great number of images of a line which, taken together, build up the form of the region from which the light proceeds. In this way the full benefit of the physiological principle is derived, and very minute differences of intensity between various parts of the solar disk are clearly registered upon the photographic plate.

It is obviously essential in photographing with the dark lines to exclude completely the light from the continuous spectrum on either side of the line employed. The admission of even a small quantity of this light might completely nullify the slight differences of intensity recorded by the aid of the comparatively faint light of the dark line. As the second slit can not be narrowed beyond a certain point, it is evident that for successful photography with the dark lines their width must be increased by dispersion in the spectroheliograph to such a degree as to make them wider than the second slit.

The first successful photographs obtained with dark lines were made with the Rumford spectroheliograph in May, 1903. The lines of hydrogen were chosen for this purpose, on account of their considerable breadth, and because of the prominent part played by this gas in the chromosphere and prominences. In order to secure sufficient width of the lines, the mirror of the spectroheliograph was replaced by a large plane grating having 20,000 lines to the inch. After leaving the grating the diffracted light enters the prisms, where it is still further dispersed before the image of the spectrum is formed upon the second slit. The effect of the prisms is not only to give additional dispersion, but also to reduce the intensity of the diffuse light from the grating

—a most important matter in work of this nature. The hydrogen lines employed were $H\tilde{\beta}$, $H\gamma$ and $H\beta$; $H\delta$ is perhaps the best of these three lines for the purpose.

On developing the first plate we were surprised to find evidences of a mottled structure covering the sun's disk, resembling in a general way the structure of the calcium flocculi, but differing in the important fact that whereas the calcium flocculi are bright those of hydrogen are *dark*. This result was confirmed by subsequent photographs, and it was found that in general the hydrogen flocculi are dark, although in certain disturbed regions bright hydrogen flocculi appear. Some of these are eruptive in character, and correspond closely with the brilliant eruptive calcium flocculi. But in other cases, in regions where no violent eruptive disturbances seem to be present, the hydrogen flocculi sometimes appear to be bright instead of dark. Such regions are usually in the immediate vicinity of active sun-spots, where it is probable that the temperature of the hydrogen vapor is considerably higher than in the surrounding regions. The spectroheliograph thus seems to afford a method of distinguishing between regions of higher and lower temperatures—an additional property which should prove of great value in investigations on the vapors associated with sun-spots. It is possible, of course, that the increased brightness is due not merely to an increase of temperature, but to other causes, perhaps of a chemical or electrical nature, which are not yet understood. But in any event, the method serves to differentiate these regions from others in which these conditions are not fulfilled, and the possibility of making such a differentiation is of value, even if we do not as yet understand the actual cause of the increased brightness.

The comparative darkness of the hydrogen flocculi evidently indicates that this gas in the flocculi for some reason radiates less light than the hydrogen gas which, probably after diffusing from the flocculi, has spread in a nearly uniform mass over the entire surface of the sun. For the present the simplest hypothesis is to assume that the diminished brightness of the flocculi is due to a lower temperature at these points, perhaps caused by the rapid expansion of the gas as it rises from the interior of the sun into the region of greatly reduced pressure above the chromosphere. On such an assumption it would seem probable that the hydrogen flocculi really represent the hydrogen prominences, which lie at a considerable height above the chromosphere, in a region of very low pressure, where the effect of expansion should have produced the greatest fall in temperature. It may ultimately appear that some other explanation must be adopted, especially since the hydrogen in the upper part of the chromosphere seems to be represented by the smaller hydrogen flocculi which form a network over the entire surface of the sun. It already seems probable, in spite of

the comparatively small width of the hydrogen lines, that it will become possible to secure photographs corresponding to different elevations,

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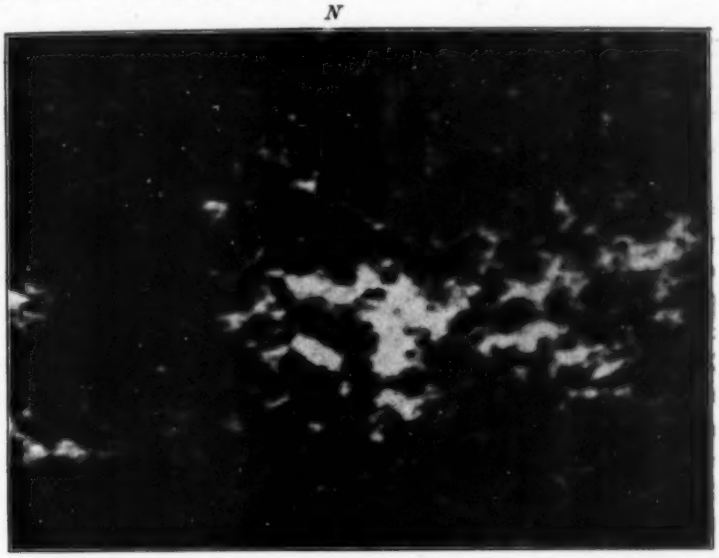

E FIG. 10.—3h 57m. Calcium Flocculi, K_2 Level. Slit at λ 3933 8. W

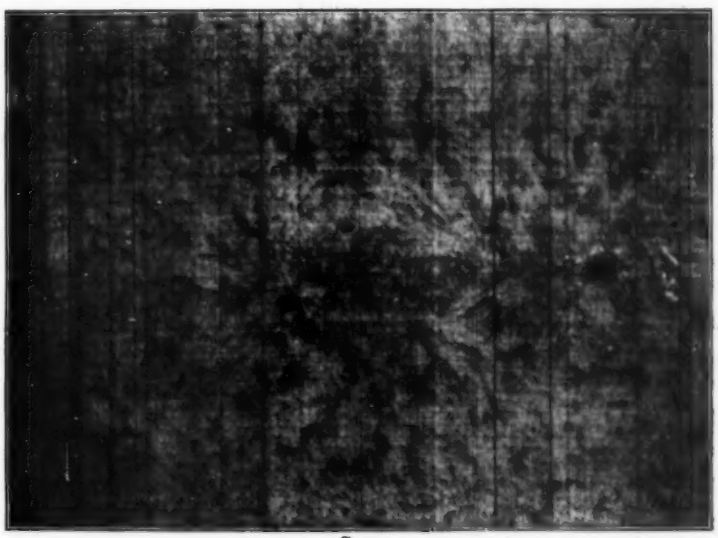

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FIG. 11.—11h 0m. Hydrogen Flocculi. Slit at Center of $H\gamma$. (Bright Eruptive Flocculi West of Spot.)

HYDROGEN AND CALCIUM FLOCCULI, 1903, JULY 7.
(Scale: Sun's Diameter's = 0.290 Meter.)

just as has been done for calcium with the broad H and K bands. This would permit the lower regions to be differentiated from the

higher ones, and thus assist toward an understanding of the true cause of the apparent darkness. A satisfactory comparison of the forms of the hydrogen flocculi with those of the calcium flocculi can only be made after the question of level has been solved. Although there is a general resemblance in form, as may be seen by reference to Figs. 10 and 11, the differences are nevertheless striking enough to suggest that various researches, interesting on physical and chemical grounds, should be undertaken in the future. For instance, a series of simultaneous photographs, in both hydrogen and calcium lines, taken at brief intervals during the course of a violent eruption, might show interesting peculiarities in the relative forms of the hydrogen and calcium flocculi, corresponding to different velocities and distribution of the respective gases.

The Rumford spectroheliograph has also been used to secure photographs with some of the stronger dark lines of iron and other substances, which show the vapors of these metals on the sun. But even with the grating, the dispersion is insufficient to give thoroughly trustworthy results, except in a very few cases. It is evident that much greater dispersion must be employed if the full capacity of the method is to be brought out in future work.

It is perhaps worth while to consider what are the logical steps to be taken in the future development of the spectroheliograph. As at present used, it is capable of solving a large number of problems if employed systematically to register the changing forms of the calcium and hydrogen flocculi. The method of photographing sections at different levels, and the method of detecting local differences of temperature or of physical or chemical state, should also permit important knowledge to be gained. But to stop at the point reached, when there is so much of promise in the further perfection of the method, would commend itself to no one interested in the advancement of research. The principal requirements of an instrumental nature are:

1. Greatly increased dispersion in the spectroheliograph, through the use of prisms or gratings in conjunction with collimator and camera lenses of considerable focal length.

2. A focal image of the sun at least twenty inches in diameter, of which zones at least four inches wide can be photographed in monochromatic light.

These considerations would point to the use of spectroheliographs, of from 12 to 40 feet focal length, provided with large gratings or with three or four prisms. Such instruments would necessarily be mounted in fixed positions on massive piers. A solar image 20 inches in diameter would involve the use of a telescope about 180 feet long, and the importance of providing for simultaneous photography in several lines at different parts of the spectrum, would require that

the sun's image be formed by mirrors instead of lenses. Thus the telescope should be a horizontal reflector of the cœlostat type. The aperture of the mirrors should be as great as possible, since the high dispersion of the spectroheliograph, even in the most favorable cases, will involve long exposures.

But the most important requisite is such a condition of the atmosphere as will give the finest possible definition of the solar image. This would involve the establishment of the instruments at some particularly favorable site, where careful telescopic tests have shown the definition of the solar image to be exceptionally fine. Such a site is most likely be found in regions where the sky remains cloudless for weeks at a time: a point of great importance, since at such a place the various phases of changing phenomena could be followed up day after day with the same instruments. A still more thorough study of constantly varying solar phenomena could be secured through the cooperation of a chain of suitably equipped observatories, so distributed in longitude as to permit the sun to be kept continuously under observation.

With such large spectroheliographs, employed with a well-defined solar image of sufficient size, it should be possible to study not only the vapors lying around and above sun-spots, but those which constitute the spot itself. With sufficiently high dispersion, for example, it ought to be possible to secure photographs with the slit set at different points on some of the broadest of the 'widened' lines, giving sections of the vapors of the dark umbra of the spot at different depths below the surface. A comparative study of the forms of the umbra, as recorded in different widened lines, and of those bright forms which must appear on photographs taken with Fraunhofer lines that are weakened in intensity or transformed into bright lines in sun-spots, should provide data for the solution of important questions relative to the solar constitution.

But the spectroheliograph, though promising to supply an exceedingly powerful method of attack, is only one of many instruments required in a comprehensive investigation of solar phenomena. Powerful spectroscopes, equaling or surpassing in resolving power the largest instruments now employed in the physical laboratory, must be used simultaneously with the spectroheliograph in a study of the various vapors. In such a research the displacements of lines in various regions, corresponding to the effect of pressure or to the motion of the gases in the line of sight, would play a prominent part. This most precise quantitative work must be accompanied by a systematic record, extending through many sun-spot periods, of the lines which are widened in sun-spots. Furthermore, there should be accurate measurements, with the bolometer or radiometer, of the heat radiated from

different parts of sun-spots and from other regions of the sun's surface. Visual studies of the solar details under the best atmospheric conditions, and direct photographs made in the ordinary way, will also be essential. From such a mass of observations, if systematically made and studied, a considerable increase in our knowledge of the solar constitution might reasonably be expected to follow.

It would be beyond the province of my immediate subject to discuss the methods by which the study of the physical constitution of the nebulæ and stars may be expected to throw light on the past and future of the sun. But I can not refrain from remarking that through recent improvements in reflecting telescopes, and through the further improvements which are promised in the immediate future, a great advance in this department of astrophysical research may confidently be expected. It thus appears that if the powerful instruments required for these investigations can be provided, the opportunity should exist during the next quarter of a century to make important additions to our knowledge of the origin and development of the sun, and at the same time to throw new light on the great problem of stellar evolution.

THE COLLEGE OF THE WEST.*

BY PRESIDENT DAVID STARR JORDAN,
LELAND STANFORD JUNIOR UNIVERSITY.

TO each century is granted one great discovery, and from this its highest thought and action takes its bent. In each century this discovery is never a new one. It has had its prophets and martyrs ages before—men whose lives have seemed thrown away until at last the world moves on and the caravan reaches their point of vision. The great discovery of the eighteenth century was that of the humanity of man. In action this became the spirit of democracy. The great discovery of the nineteenth century was the reality of external things. Carried out into action this means the progress of science. It is the movement of science which makes possible the varied activities of the new twentieth century.

We are gathered together this morning of the twentieth century to dedicate a new hall of science, a new temple to the worship of the truth of nature. It is erected that it may help men to know and to know what they know—to separate their knowledge of realities from their feelings, their hopes, their dreams, their traditions. All these may be beautiful, helpful, inspiring—but truth is something more than subjective satisfaction. To that part of the divine outside of ourselves which we are able to grasp we give the name of science.

In what I may try to say this morning, I shall speak freely in praise of science, of science study and science teaching. It is for this that we are gathered together. When we erect the hall of the poets, then our discourse may be on Euripides and Shakespeare, on Schiller and Browning, and some gentler tongue shall speak the fitting word. Each power of man shall be exalted in due season and no one at the expense of another. It is true that science is a late comer into the educational household, and that finding none too much room at the best, she sometimes unwittingly ventures to claim it all. But that is only for the moment. Knowledge of man and knowledge of the universe do not exclude each other. In urging the claims of science we would not deny one word ever said for training in the humanities or in any branch of these. This only would we claim. There exist forms of culture other than those which rest on the classical tripos. Other men with other powers have an equal right to training. There is no aristocracy in the human mind. Moreover, prescribed courses of study, whether classical

* Address at the dedication of Palmer Hall, Colorado College.

or scientific, or whatever else there may be, must give way to the needs of individual training. Ready-made clothing, even though it take the form of heroic uniform, does not guarantee a fit. The needs of modern life demand actual fitting. The best training is that best adjusted to our own individual needs.

I am told that Colorado College is one of those which aspires to be 'only a college,' a thoroughly good college of course, but that she has no thought of becoming a university. I do not learn this from my friend, Dr. Slocum, and I know that his ambition is boundless. But whether it be true or not, I am going to oppose the idea. She will be a university before you know it. This Palmer Hall may be offered in evidence that the college period is past. Colorado College has already become a university. A university in embryo, perhaps, if you like, but still with all the marks by which the university is known—as certain to become a university in fact, as a pine seedling on your royal hills is sure some day to become a pine tree.

A university in America is a place where men find their life-work, where men think lofty thoughts, where men test for themselves that which seems to be true, where men go up to the edge of things and look outward into the great unknown.

The university does not consist of colleges and departments, deans and dignitaries, rules and regulations. It is not a cluster of professional schools, nor even a group of graduate students. Its spirit is not measured by printed theses, by elaborate examinations, by the number of the hoods of black and gold its doctors are privileged to wear. It is measured by the animating spirit, the spirit of intellectual enterprise, of academic devotion. This spirit will in time create for itself the brick and stone, test-tubes and microscope, book and manuscripts, all the machinery with which a university must work.

In the development of an animal there is a subtle influence, which we can not measure, always at work, and working to the end that the embryo becomes at last that which from the first it was fated to become. We call this the influence of heredity, but to name it leaves more to be explained than there was before. In like fashion, the spirit of the university, the spirit of zeal and devotion, of beauty-loving and truth-fearing which is in Colorado College to-day will make the university an accomplished fact. Truth-fearing—there is no better phrase —truth-fearing is the spirit of the university.

There is no real difference between the American college and the university, and there will never be any. The lower achievement leads to the higher ambition. Many colleges are little, or weak, or lean or narrow universities; yet even the poorest of them may be hallowed by some one's devotion, ennobled by some one's scholarship. It is scholarship and devotion which, in the long run, make the university. Cer-

tain genuine attributes of the true university we may see clearly in Colorado College. For one thing, she is broad-minded. The hall we dedicate to-day stands as one evidence of this, her fair library is another, and still more cogent the wide sympathies and helpful achievements of her professors. I believe most firmly in the educative value of unlikeness in aim and thought. A man may be highly specialized, he must be if he would succeed as an investigator; but a university should be an all-around organism. The school of applied science, the school of literary expression, should not stand apart from each other. The engineering student is likely to become illiterate if he herds only with his kind. He learns many lessons from the finer side of life, from the student of Chaucer or Homer. The literary student tends to become a dreamer or a prig if he is in touch with literary matters only. From the fierce earnestness of the young engineer, whose whole career depends on the soundness of his individual work, the student of the humanities gains most valuable lessons.

For the same reason I believe in the coeducation of men and women. They need not study the same things, though for the most part as beauty is beauty and truth is truth, so mental accuracy knows no distinction of sex. But the influence of wise and cultivated women works for manliness and refinement. The influence of hopeful and strenuous men gives women's work a seriousness and sanity which is a fair exchange for the other. Where coeducation is honestly and rationally tried, it is no experiment at all. In the natural order of things, and in the long run, the American university and every other real university will be a school for men and women, opening its doors to all who can use its advantages or who can share its ideals.

Wherever there is a real scholar—independent, self-reliant, truth-loving scholar—there we have a university. He gives the university uplift, the university inspiration, the university ideal. If he has but one student, that one is a university student. I do not know how many such there be in the faculty of Colorado College, but there are some I know; some peaks which catch the morning sun, and in the presence of these we have the essential element of the university.

In the American scheme of education, the college course is a period of intellectual broadening. It makes men, while the university makes scholars. The German university system admits of no college course. The college is not the American gymnasium. The rigid drill of the gymnasium, intense and narrow, gives way at once to the university when any subject can be pursued in any fashion or no fashion at all. The gymnasium has cast iron walls. She takes no account of individual differences; she will drill but not create. The university is wide open, everything is at the student's hand: science, letters, art, lust or beer. The student chooses for himself, and the university, as an organism, is indifferent as to his choice.

The American university cares for its students, unwisely sometimes in nagging or futile fashion, but still on the whole to their great advantage. She is always a cherishing mother, and as such her children love her. I have never heard a German university called *Alma Mater*. 'Liebes närrisches Nest,' 'dear silly nest.' This Goethe once called Jena, but Jena was held in remembrance not for her loving care, but for the fond follies she, uncaring, allowed her sons to perpetrate. The German university makes no effort to see that her students work wisely, or indeed that they work at all. They are weaned once they leave the gymnasium. There are too many of them anyhow. Most of them go to swell the 'intellectual proletariat' which, so the Germans tell us, with the military proletariat, is a national menace, and so what does it matter?

Bismarck is reported to have said that one third of the German students drink themselves to death, one third die of overwork and the rest rule Europe. In America, the college has tried to change these proportions, college professors have thrown their personal influence to induce young men to lead sane and profitable lives, to keep them from throwing away their future till the time comes to rule. In this work the faculty of Colorado College has long taken an honorable part. It has shown the value of personality; men are saved by fellowship as often as by precept or practise. By personality is built up the college atmosphere, the 'fellow feeling among free spirits,' an agency in higher education as subtle as it is effective. For this reason the value of the college depends largely on the nearness of the professors and students—'They know each one of us by name.' This has been declared as the secret of the education of old Japan. Not professors, not masters, not martinets of high or low degree, but men who were fellow students have been the most successful teachers. The value of a teacher decreases with the increase in the square of the distance from the student. In this matter the smaller universities have a great advantage over the larger ones if they will only be as careful in the choice of teachers. Only those who are near him know that a teacher is great. There are many graduates of our strongest institutions who never in their whole four years came in contact with a professor. Not long since, the editor of an eastern magazine, an able student and a man of strong character, told me that in his college course he had a speaking acquaintance with but one professor. There were a hundred in the faculty, many of them men of high distinction, but what was that to him? His work was laid out for him in a prescribed course, long before he was born, and from young instructors he received all his guidance.

In this lies one value of the study of science. It has but one method, that of the laboratory, that of first-hand contact with the

things as they are. The teacher himself is a part of that contact. He has set the problems, arranged the experiments. The teacher of science does not speak *ex cathedrâ*. He must come down from his chair. He must be among the things of which he speaks and to the student he must be part of them and the student knows him as he knows them—from personal contact. The strength of the colleges of England has lain not in the narrow courses of study, not in the exclusive pursuit of Latin, Greek and mathematics, but in the spirit of good fellowship which these institutions have fostered. The life of the student is a man to man life. The element of personality has been used to the utmost and with results which need not be disparaged even by those most impressed with the narrowness of the training these colleges offer.

The aim of Oxford and Cambridge has been personal culture. The classical tripos of Greek, Latin and mathematics has been only a means to this end. Any other studies, Anglo-Saxon, botany and medieval history, let us say, would do as well if equally removed from the current of human activity and brought as close to living personality. Mere training of the mind was no essential part of the process. To withdraw for a space in the presence of good men and gracious thoughts is an ideal cherished in English culture. 'Sometimes to bask and ripen,' Lowell tells us, 'is, methinks, the students' wiser business.' For the maturing scholar this may be true, but as a practical matter it is surely a universal experience that to the college student 'to bask and ripen' means a period of plain idleness, and idleness soon turns to dissipation and vice. It is better for the student that demands on him be somewhat strenuous. His life is made more effective if he has once learned the value of time and the necessity of doing things when they should be done. A man who has not learned the worth of time before he is twenty-one, seldom accomplishes much afterward. As the university ideal of England is one of personal culture, that of Germany is one of personal knowledge. In the one case, thoroughness is the essential; in the other, personality. An educated German may lack culture—of this there are many conspicuous examples, just as in England a cultured gentleman may lack exactness of knowledge on all points. In America a new ideal is arising as a result of the creative needs of our strenuous and complex times. We value education for what can be made of it. Our idea is personal effectiveness. We care less and less for surface culture, less and less for mere erudition. We ask of each man not what he knows, but what can he do with his knowledge. This ideal of education has its dangers. It may lead us to sacrifice permanent values for temporary success. It may tend to tolerate boorishness and shallowness, if they present the appearance of temporary achievement. Eternal vigilance is the price of scholarship as well as of liberty and other good things.

But the fact remains, the value of science lies in its relation to human conduct. The value of knowledge lies in the use we can make of it. As each thought of the mind tends to work itself out in action, so does each accession of human knowledge find its end in fitting men to live saner and stronger lives. We may, therefore, rest content with the ideal of effectiveness. The American scholar is master of the situation. He can make things go, because he understands them and because he understands himself. He does not shrink from that which appals the men of culture. He is adequate for that which bewilders the erudite. Judged by our best products, there is no finer man on earth than the college man of America, and in proportion, in the future, he will be wiser and more forceful than he is to-day.

In mechanics we know that the force of a moving body is not measured by its substance. Its momentum or effective power is found in its weight multiplied by its speed. This illustration has been used in praise of American science. The power of science lies not in individual erudition. It lies in its striking power. American science is dynamic, it is always under way. In every branch of science, the best American workers have been those most strenuous in their personal efforts, most eager to make their work useful to the world at large. In almost every branch of utilitarian science, America already stands in the lead. This fact England has already recognized with dignified dismay. We hear much of it now, we shall hear more of it still later, for quite as remarkable as the growth of American science is the advance of American schools. Whenever I visit a department of applied science in America, I see that it has doubled its power, its staff and its equipments since the time of my last visit. My visits are not very frequent, perhaps once in five or ten years, let us say, but what will be the end of it? To double once in fifty years is a rare thing in the universities of the old world, but even that in a few centuries would accomplish wonders.

It is one of the laws of mathematics that a geometric progression will long outrun an arithmetical progression, whatever increases by doubling will far exceed the bulk of addition. American science and scientific schools increase by doubling, and will continue to do so. Hence we measure them not by their actual achievements, but by the certainty of a greater future, far beyond the dreams of those who, like ourselves, must be numbered always with the pioneers. To lay the foundation of science, the foundation of knowledge, the foundation of the future commonwealth of Colorado, is the work of the pioneer. Ours then is a glorious part, for the pioneer is a noble function indeed, but the actuality for the future will surpass the brightest dreams of to-day. Let us glance at some of the varied thoughts this enterprise suggests.

A hundred miles away at the foot of the same mountain range lies

your sister university, the official child of the state. It is for you and for her to work in unison, the same in final purpose, somewhat different in the way of reaching it. The most wonderful thing in educational development since Alfred founded Oxford and Charlemagne Paris, has been the rise of the state universities of America. These are schools established by the people, paid for by the people, built for their own good, limited by no tradition, but rising in power and usefulness with the rise of the common man's intelligence and wealth. Great men have built them but these were not kings, nor millionaires, nor politicians, nor priests. They were simply school teachers, with the common man behind them. The material support of the University of Colorado is the personal interest of the many. The support of Colorado College is the intensive interest of the few. The word *intensive* suggests the nature of her opportunities. The state university must concern itself largely with the development of the professions as a whole, the general intellectual welfare of the state. Every citizen has a stake in it, each citizen has the right to make a demand.

The independent college can make its own clientage; Colorado College is not confined to Colorado. It may be cosmopolitan. Its mission is not to raise the level of professional work or of intellectual life in Colorado. It can aim at higher results, though they be less broad, to give the exceptional man or woman an exceptional opportunity, through the use of the finest agencies within a narrower field. Along this lies the future of the privately endowed colleges and universities. We may not do all things worth doing, but we can do some things better than the state universities can, by virtue of an independent position. The superiority of the independent college must be real so far as it goes. It may lie in research, in excellence of teaching or in the loftiness of personal influence; its range may not be so broad, but it may rise higher, it may come nearer to the heart.

I could not be a son of my own fair state, a 'native son' by adoption, did I not say a word as to the glorious climate which Colorado College may add to the roll of her advantages. Here in Colorado, as in California, nature is kind to man, the weather never makes him its slave, never shuts him up to stew in over-heated prisons.

Colorado, like California, is a virile state, one of 'earth's male lands,' to adopt Browning's classification. It has, like California, the three splendid attributes of healthful air, magnificent scenery and physical and mental standing room. It breeds independent, all-around men. Colorado flows red blood. She has the out-of-doors atmosphere —freed from the narrow cramped public opinion that is made in over-heated houses, the public opinion of the village of white houses and green blinds, where everybody knows everybody's business. It has the public opinion of the man who stands on his own feet, cares for his

own needs, is sufficient unto himself and has the large charity which sound nerves ensure. The way of Colorado is the warrior's way—'the Bushido,' as they said in old Japan, the way of the rough rider, the way of the quick arm and the tender heart, the way of him who cares only for what men are and not at all for what men say.

Weak men who have been kept good in the east through the upbraiding of maiden aunts often fail in Colorado. Good men grow better there, for they must fight for and justify their virtue. After all that is the only kind of righteousness that counts, vast, burly, aggressive righteousness to which sin is folly; selfishness and vice are things to be avoided as contemptible, as well as shunned as wicked. The scholar in Colorado shares the largeness of his field. The dim-eyed monk, the stoop-shouldered grammarian, these are not his ideals. The scholar is the leader of enterprise, the builder of states.

The air of Colorado is charged with oxygen. It is good atmosphere in which to bring up a boy. In Colorado he becomes an out-of-door man. He expands his chest, he can do things, he becomes fearless because he is adequate. Here in the west we send our graduate students to the east, because we know that it will be well for them to know what homes their fathers came from. They need New England acquaintanceship, English culture and German methods of thought. Far more does the eastern graduate need what the west can give. The life in the foothills makes a man, if need be, of the Harvard doctor of philosophy. The world beyond the Missouri spreads his horizon and the swift oxygen in the Colorado sunshine swells the size of his heart. Some day men will go to Colorado and California for inspiration of force as poets go to Greece for the inspiration of beauty.

The new America is born where things are broad and free, and her finest inspiration where things are grand and strengthening. When the days of the emigrant are over and our people reach their equilibrium, the home of the highest education must be in the west. Whoever has known Colorado, whoever knows the great west will, all his life long, always hear it calling, and wherever he goes he will carry with him a fuller heart and a freer hand for his life in the plains or the foothills, for his life in the regions where the very heavens are cosmopolitan.

I might say a word on the field of local scientific study which Colorado offers. The problems of the local geology have been discussed by my colleague President Van Hise. A region as vast as the Mississippi valley has been crumpled and folded in the stress of the earth to make Colorado. Noble scenery is the raw material of geology. A mighty cliff is an uncovered record of primeval history. In all this history, from the earliest to the latest, Colorado has something to say. The graves of our earliest ancestors, it may be, lie in the hills of

Cañon City. In these rocks at least are found the earliest traces, the earliest by a million years perhaps, of any backboned animals. From these it is a far cry indeed to the shales of Florissant, where in their day the earliest birds went out to catch the latest worm there was, and again to the Green River shales of the northwest with their extinct creatures not very different from their descendants of to-day. When we speak the magic names of Uncompahgre, Ouray, Telluride, Las Animas, Sierra Blanca, Pike's Peak, Long's Peak, Gunnison, Manitou, Saguache—I know them all and know them well—we raise a thousand memories of grand scenery, rich mines, geological problems, the crumpling of continents, the wash of great rivers.

The botany of Colorado runs rampant over all the hills, columbines and gentians, primroses and poppies; sunflowers and lilies; mountain and plain; Colorado is a land of flowers, and better than this, it is a land of problems. Where did they come from? How did they get here? How did they, why did they change? What relation had the movements of the flowers to the vanished glaciers which have left their imprint in lake and moraine, in erratic and sheep-back and furrowed rock, over so much of the surface of Colorado?

In zoology there is equal richness of forms and equal wealth of problem. How came the trout to move from river to river, changing its spots with every change of stream? How did it pass from the Missouri to the South Platte without reaching the North Platte? How from the Platte to the Arkansas with scarcely a change of any kind? How from the Arkansas to the Rio Grande with changes that every angler notices? How again from the Rio Grande to the Colorado? How from the Colorado across the main divide to the Twin Lakes of Leadville? These are problems worthy of a Sherlock Holmes, and the methods ascribed to that mythical personage are the ordinary methods of science. The same process is used, but it is turned to a higher end than the hunting down of human sins and follies. The problems of geographical distribution, their facts and the causes which lie behind them, occupy a steadily increasing place in the world of science and for the study of very many of these problems there is no field so promising as Colorado.

I can not close this address without a word in praise of the honored president of Colorado College. It is the highest duty, the noblest privilege of the president of the college to give the institution its personality. Others may give money and buildings, the state may create machinery by which the college works; it remains for him to make it a living person, an *Alma Mater,* an influence in the formation of character and citizenship. Sixteen years Dr. Slocum has struggled for Colorado College. Sixteen years of courage, devotion, persistence, of a type few other colleges have known. He has sought far and wide

for good men, for men of his kind. He has seen richer institutions draw these men away, and then he has begun his search once more, and each time he has closed the ranks with men of the Colorado spirit. Every great university has been enriched by men drawn from Colorado College. Greater institutions have stood ready to bid for his own services, and in no mean fashion. This I know well, though not from him. But he will not leave the work of his life to begin another, simply because the other stands in a larger yard. There is gold in Colorado, there is silver, there is untold wealth in her mines. But Colorado is not made by mines. She has been made by men. She has had many red letter days. This twenty-third day of February, 1904, is not the least of them all, but none has been fraught with greater hope to the state than that day sixteen years ago, that day when William Frederick Slocum came to the presidency of Colorado College.

The building we dedicate to-day is called Palmer Hall. It is in large degree the gift of General William J. Palmer, and it rightfully bears his name. I never met General Palmer personally until yesterday, but I have long known his name as that of one of Colorado's most enlightened citizens. I trust that he may live long to see his noble gift used and appreciated.

There is no way, I believe, in which accumulated wealth can be so wisely used as in the endowment or enrichment of colleges. In no way can the present secure such pledges of the future, and no gifts are so unselfish as those made to posterity. All who help to promote scholarship, citizenship, efficiency, are patriots in the highest sense and their patriotism should be appreciated by the people.

In all the range of mean-spirited criticism there is nothing more contemptible than that which ascribes selfish aims to wealthy men who give to colleges. Sensational neurotics are constantly in fear that the rich man will force the college to teach his doctrines. Such a thing has never happened, for it requires brains to acquire wealth and this implies sense enough to understand the freedom of the university. No rich benefactor of our day has ever tried to use a university as a tool; no one ever will try. Yet the clamor having this as a burden goes up from one end of the country to the other. Over the shoulders of the college the blackmailer tries to stab at the millionaire. But he goes on his way unmindful, and if he be generous-minded, he makes his gifts just the same, sure of the results of the future, even though denied the gratitude of the present.

Here in Colorado there rules a saner spirit. Our Palmer Hall is the gift of a kind and helpful friend. As such it is received by all who are here to-day and by all true and loyal citizens of Colorado.

Finally let me say: In all plans of university building there is but one that succeeds. Those who think for themselves will inspire

others to do the same. Where teachers are original investigators truth-fearing and truth-loyal men, men that can not be fatigued or discouraged, their students will be of their own kind. To find them, they will come from the ends of the earth. The investigators make the university as the teachers make the college. It is not necessary that many departments be developed to make the university real; it is said that Agassiz in 1850 was himself the sole university in America. The presence of Agassiz and Gray, Lowell and Longfellow, Holmes and Goodwin, Felton and Norton, meant a university atmosphere. Silliman and Dana meant the University of Yale. Such men are as rare as they are choice. No university faculty was ever made up wholly of university men, and no one ever had too many of them.

From such men as these the American scholar is descended. The growth of American science is his work, and of this growth he is in turn a product. That he may never grow less we hope and pray. And this with a certainty that our prayers will meet their answer. Our faith is shown by our works. With the best of these let us place our new temple dedicated to the holy life of action, to the worship of the God of things as they are, our new Palmer Hall of Colorado College.

A QUESTION OF PREFERENCE IN ENGLISH SPELLING.

By Dr. EDWIN W. BOWEN,
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WE little think when we read or write that the words we employ are not precisely the same as those which have been in use in our mother-tongue from time immemorial. We are born into the language, so to say, and the words of our vocabulary we regard as part and parcel of our rich heritage of American liberty. Yet even the words of our English speech, like many of the institutions and customs of our Anglo-Saxon civilization, have a long history back of them, showing traces here and there of the various stages of development they have passed through. The words we use to-day are not identical in form or meaning with those employed by our forebears of the generation of Chaucer or even of the generation of Shakespeare. The forms of our English words have undergone considerable change since that remote period in the development of our mother-tongue. English spelling is far different from what it was in Alfred's, or Chaucer's time.

Before the invention of printing, those who spoke and wrote the English language seem to have been at liberty to spell as they chose. Their mental composure was not disturbed by the annoying suspicion that their spelling was not according to the norm prescribed by the dictionary. In those good old days there was no acknowledged criterion such as the 'Century,' or 'Webster,' or 'Worcester'; and writers had no final appeal in the matter of orthography as present-day writers have. Since there was no standard authority on orthography to which all polite society had to conform, the authors of the thirteenth and fourteenth centuries were untrammeled by tradition and were free to spell as they pleased. Every writer was a law unto himself and followed the dictates of his own orthographical conscience, with no dictionary to molest or make him afraid. We find an allusion to this delightful sense of freedom in the comment which a well-known American humorist made upon Chaucer, that well of English undefiled from which so many modern writers have drunk copious draughts of inspiration. 'Chaucer,' said he quaintly, 'may have been a fine poet, but he was a —— poor speller.'

The diffusion of the art of printing and the consequent necessity for a uniform orthography gradually curtailed this liberty, and then the day of the dictionary dawned. The dictionary is a democratic

invention called into being by the rise of the great middle class of society, which desired to become familiar with the practises of polite circles. Lexicographers came forward to supply the desired information. Authors not to the manor born, and therefore unacquainted with courtly usage, when moved to write, felt that they must conform to the standards set up by the lexicographers, who claimed to give the received usage, the *jus et norma scribendi.* Before the epoch of dictionaries it appears not to have made the slightest difference whether a writer spelled the word *recede,* for example, according to the present accepted orthography, or whether he spelled it *receed, receede, receade* or *recead,* all of which forms are found in manuscripts of a few centuries ago. Some of these orthographic variations lingered into the eighteenth century, though English spelling had probably become stereotyped at least a century before this date. Yet the establishment of the spelling was naturally a gradual process, and some words vacillated a long time and never really became fixed. Of this more anon. Proper names showed considerable latitude of spelling. Men of the eminence of Spenser, rare Ben Jonson and Shakespeare, for example, are said to have had no fixed practise of spelling their names, but wrote them in a variety of ways.

The lack of a standard authority of orthography necessarily gave rise to much confusion and disorder in English spelling. This confusion is reflected even yet in the present chaotic and unphonetic spelling of our language. Few tongues are more unphonetic than the English. This fact is recognized and efforts have been made to bring our spelling into closer conformity with our pronunciation. Philological societies on both sides of the Atlantic have been trying for the last quarter of a century, at least, to reform English spelling; but only meager success has been achieved thus far.

The proposed reforms have been of two kinds, and they have varying aims. One, recommended by the extreme phonetists, is a reform which contemplates a revision and enlargement of our alphabet. This would result in a radical transformation of our written speech, and chiefly for this reason it has found few ardent advocates. It may be briefly described as a reform of the language. The other reform is less revolutionary and contemplates mainly a simplification of our present spelling, such as the omission of silent letters, the substitution of 'f' for 'ph' as in *phonetics* (fonetics) and of 't' for final 'd' as in *equipped* (equipt) and similar emendations. Of the two kinds of reform the latter has, manifestly, more to commend it to popular favor. This kind of reform may be termed a reform in the language.

The public concedes the unphonetic character of English orthography, but the conservatism of the Anglo-Saxon race is so binding that the people are slow to adopt even the slightest recommendations of the philological societies. A few American journals have had the courage

to adopt certain emended spellings, such as *thru* (through), *tho* (though), *catalog* (catalogue) and the like, but the majority of our periodicals show by their practise very meager approval of spelling-reform. No publisher, so far as known to the writer, has ventured as yet to use the emended spelling in a book issued by his firm. Yet all admit the need of spelling-reform and believe that, if adopted, it would save the coming generation a vast deal of humdrum work in acquiring an accurate knowledge of English orthography.

We Americans, however, with our characteristic spirit of independence have made bold to break away from British tradition and custom in the writing of certain English words and have introduced a few minor reforms in our spelling. But the English people have not followed our lead in this matter, being content to allow our adopted American spelling, together with our distinctive pronunciation, serve as an earmark to distinguish American from British English. It is the practise of some reputable British journals to disparage our spelling, wherever it makes a departure from English traditions, and to refer to it by way of reproach as 'American spelling.' Some few years ago the *St. James Gazette,* intending to express its disapproval of our spelling, deprecatingly remarked that "already newspapers in London are habitually using the ugliest forms of American spelling and those silly eccentricities do not make the slightest difference in their circulation." Viewed in the light of subsequent events, perhaps this ought to be considered as the forerunner of 'the American invasion.'

As every one knows who has visited the mother country, there is a perceptible difference not only in the spelling, but also in the pronunciation, between American English and British English. Of course the language is the same in America as in England; and yet there are some appreciable minor points of difference. For example, the Englishman gives the broad sound to the vowel *a* as in *father,* when it is followed by such a combination of consonants as in the words *ask, fast, dance, can't, answer, after* and the like. In America, on the other hand, while this pronunciation is heard in some circles, it is clearly not the ordinary pronunciation and is not general, as in England. There is also a noticeable difference in the pronunciation of long *o,* the Englishman giving the vowel a distinctive utterance quite unlike that ordinarily heard in America. The pronunciation of the word *been* is a shibboleth by which a man of British nationality may be almost unfailingly distinguished. The native Englishman pronounces the word so as to rhyme with *seen,* never *bin.* In addition to these points of pronunciation there are certain locutions which never fail to betray an Englishman. The English call an elevator *a lift,* overshoes *galoshes,* napkins *serviettes,* candy *sweets.* In England a baby-carriage is called a *perambulator,* which is generally abridged *'pram'* merely; a lamp-post is known as *lamp-pillar* and a letter-box

as a *pillar-box*. There no one would ask at a store for a wash-bowl and pitcher, however much he might need these useful household articles, but he would call at the shop for a *jug* and *basin*. An American in London must not say street car, but *tram* or *road car;* not engine (which is pronounced injin), but *locomotive-engine;* not engineer, but *engine-driver*. In England many ordinary household articles are known by names as different from those in our country as if the language there were altogether a foreign tongue. Small wonder, then, that a keen-witted American maid remarked, *à propos* of the difference between British English and American English, that London was a delightful place if you only knew the language.

Nowhere is the difference between American English and British English more marked and interesting than in the varying practise of spelling on both sides of the Atlantic. Let us note some of the chief points of variation.

Our British cousins assume an exasperating air of superiority when they mention the matter of our spelling and, as self-appointed conservators of the language, point out what they are pleased to style the offensive eccentricities of American spelling. The British journals ever and anon draw attention to our manner of writing such words as *favor, honor, center, program, almanac, tire, curb, check* and *criticize* and the like, which they spell *favour, honour, centre, programme, almanack, tyre, kerb, cheque* and *criticise*. Now, in the case of most of these words, we submit that the American spelling is nearer the historical spelling, simpler and more logical than the British method. As for the words typified by *honor,* our method is simpler and nearer to the ultimate etymology. These words, it hardly need be observed, are borrowed from the Latin through the French. The British maintain that for this reason the spelling ought to conform to the French fashion. But they overlook the fact that these words have not always been written in English according to the French manner of writing. Dr. Johnson, the eminent lexicographer of the eighteenth century, wrote *honor* beside *honour, neighbor* beside *neighbour, harbor* beside *harbour* and the like. Indeed, the great Cham allowed himself considerable latitude in the matter of English orthography. Moreover, the Norman-French forms of these words were written in a variety of ways, as *our, eur, ur,* and also *or*. Even on the historical ground, therefore, there is not lacking some authority for the American spelling. If the English were consistent, they would be forced by the logic of their argument to write uniformly *govenour, errour, emperour, oratour, horrour* and *odolour* as well as *honour* and *favour*. But practise shows their glaring lack of consistency, since they do not spell these words ordinarily with *u*. It ought not to be regarded as a reproach upon American spelling, because in our desire for simplicity and uniformity we have rejected the *u* in this entire class of words

like *honor,* thus making the spelling more in keeping with the Latin derivation. We can at least lay claim to simplicity and consistency. If we are provincial, we can not be charged with arbitrariness in our spelling.

As for the writing of *center, meter, meager* and words of this kind, the American method has as much history and logic in its favor as the British spelling has. Analogy, too, if that may be cited as an argument, supports our spelling, for we all write *perimeter, diameter,* never otherwise, whether we be American or English. The word *center,* according to Lowell, who was no mean authority on matters pertaining to our speech, 'is no Americanism; it entered the language in that shape and kept it at least as late as Defoe.' "In the sixteenth and in the first half of the seventeenth century," declares Professor Lounsbury, in reference to the spelling of *center* and similar words, "while both ways of writing these words existed side by side, the termination *er* is far more common than *re.* The first complete edition of Shakespeare's plays was published in 1624. In that work *sepulcher* occurs thirteen times; it is spelled eleven times with *er. Scepter* occurs thirty-seven times; it is not once spelled with *re,* but always with *er. Center* occurs twelve times, and in nine instances out of the twelve it ends in *er.*" John Bellows, in the preface to his excellent French-English and English-French pocket dictionary, states that "the Act of Parliament legalizing the use of the metric system in this country [England] gives the words meter, liter, gram, etc., spelt on the American plan." It is evident, then, that our way of writing these words is quite as logical and as much warranted by the history of our tongue as the British spelling.

The American orthography is clearly in advance of the British in the word *almanac.* This word is not rightly entitled to the final *k,* as the English spell it. This superfluous letter is a mere survival from a former way of writing, no longer in vogue. It has been rejected in *music, public, optic* and similar words which are written alike on both sides of the Atlantic. In Johnson's dictionary and also in our King James's version of the Scriptures the old spelling generally occurs. Indeed, Johnson appended the excrescent *k* to well-nigh all words of this class. Strange to say, there is one word of this class which preserves the *k* even in American English, and that is *hammock.* This is but an exception which goes to prove that even American English with its revised orthography is still far from being phonetic.

In regard to words ending in *ize,* usage in Great Britain has established the writing *ise,* as in *civilise.* However, new formations even there are usually made to terminate in *ize,* which is generally adopted in America. Yet American spelling sometimes exhibits *ise,* after the English fashion. The British writing is derived from the French, whereas the American harks back to the original Greek suffix. The

British spelling of *tyre, kerb, programme* and *cheque* perhaps has as much to commend it as the American *tire, curb, program* and *check*. Usage in America varies in the case of *program*, the more conservative still clinging to *programme*. *Tyre* and *kerb* are but little employed here. These words are merely variant forms which British usage has adopted. The spelling *cheque*, in general use in Great Britain for our bank check, has resulted through the influence of the word *exchequer* with which it is connected.

The usual American spelling of *wagon* is held up to public obloquy by British journalists, who regard *waggon* as the orthodox orthography. Skeat, who gives both forms in his etymological dictionary, asserts that the doubling of the *g* is simply a device to show that the preceding vowel is short. In the early history of the language when the etymological spelling was in vogue, pedants had recourse to this method of changing the form of a word to make it phonetic, as they claimed. In point of fact, by their practise they made the language far less phonetic. Spenser and other early English authors write the word after the American fashion. Horace Greeley once made a departure from our American usage and wrote *waggon*, saying by way of apology, when his attention was called to it, that 'they used to build wagons heavier in the good old times when he learned to spell.'

It is not to be supposed for a moment, however, that our utilitarian disregard of tradition is so strong as to have eliminated all useless letters in our American spelling. There is many a word in which an epenthetic letter is still retained merely because the traditional spelling shows it. *Sovereign, comptroller, island* and *rhyme* may be cited as examples in point. Perhaps it ought to be added that the emended spelling *rime* for *rhyme* appears to be meeting with favor in certain philological circles.

There is one class of words which does not exhibit a uniform method of writing, either in Great Britain or in America. This class is typified by the words *traveler, counselor, worshiper* and the like. It will be readily seen that these words are all derivatives, formed from the primary by the addition of a suffix; and the writing vacillates between a single and a double consonant preceding the suffix. According to the well-known principle of English orthography, these words are not entitled to a double consonant, and therefore should never be written *traveller, counsellor* and *worshipper*. The rule is, if the final syllable of a word ending in a single consonant and preceded by a short vowel is accented, the final consonant, on the addition of a suffix beginning with a vowel, is doubled; but never otherwise. Thus we write *offered, deviled* and the like, but *referred, transferred* and *jammed*. Hence the orthodox spelling should be *traveler, counselor, worshiper, unrivaled* and the like. But practise shows that either spelling is regarded as correct on both sides of the Atlantic. These

words are survivals from a former period in the history of the language when more latitude was allowed in English orthography and there was no hard and fast line drawn, no fixed standard. The proper historical spelling, it is interesting to note, is with one consonant, as in *counselor* derived ultimately from the Latin *consiliarius*. While either spelling is considered correct, British usage favors the double consonant (*counsellor*) and American the single (*counselor*). Here again as elsewhere American spelling inclines to simplification and would make these words conform to the general rule of English orthography as laid down above. Strange to say, British usage shows one exception in the word *paralleled*, which it has adopted (and not *parallelled*). Here we find another instance of the striking inconsistency of British orthography. It may be a shocking thing to say, but investigation will prove it true, that if those British critics who censure our spelling so severely, as offending their esthetic sense, were more familiar with the history of the language, they would, without doubt, have far less comment to make upon the so-called eccentricities of American spelling.

It remains to notice some apparent exceptions to the rule of English orthography stated above. Noteworthy among these are the words *handicapped* and *kidnapped*, which are written alike in British and American English. But they can be explained and are only apparent exceptions. A moment's reflection is sufficient to convince one that *handicap* and *kidnap* are not simple words, but in reality compounds in which the last element has not completely lost its identity in combination. Because of the consciousness of the independent words *cap* and *nap* in these compounds, they conform to the rule as a matter of fact and therefore double the final consonant, on the addition of a suffix beginning with a vowel. Hence, if they are exceptions, they must be considered exceptions which prove the rule.

The few points we have drawn attention to in this imperfect little sketch are enough to show how unphonetic and illogical is our English spelling. Many of the eccentricities of our orthography, according to Skeat, have resulted from the futile attempts of pedants in the sixteenth century to make English spelling etymological and to make it conform to the classics, from which a vast multitude of words had been introduced into our speech. These conscious attempts at etymological spelling gave rise to endless confusion and disorder. But other causes, such as analogy and mere caprice, also contributed to this end. Thus we are to explain the writing of the word *female*, for example. This word, coming from the Latin *femella* through the French *femelle* into English, was originally written *femelle* and would probably have retained this form to the present time. But because of a fancied connection with the word *male*, the spelling was changed to *female*. In a similar manner is to be explained the spelling of numerous other words in our language which seem perfectly natural and logical on first blush.

ALUMNA'S CHILDREN.

By AN ALUMNA.

THE latest publication of vital statistics in Massachusetts has again called attention to a subject often discussed in this magazine and elsewhere—the decreasing number of children in native American families. According to the majority of opinions given, this decrease is due mostly to 'social ambition.' This means that the women who should be, in a real sense, the pillars of our society prefer other things to bringing up their own children. If this is true, it seems a very serious indictment of the American woman.

But is the case settled yet? While social ambition may be operative in many cases, perhaps peculiarly among those coming to the notice of a specialist in medicine, may there not be some data that the statistician can not collect—some pertinent facts which in the nature of the case are not within reach of the investigators?

Among all the talk by learned men and high officials, it is strange that no member of the class under discussion has spoken to the question. On further thought the reason is obvious; the case is necessarily of great delicacy and incapable of proof. But because the charge seems to me in many cases so peculiarly unjust, hereby do I rush in where angels have feared to tread.

Dr. Engelmann in his especially interesting article spoke particularly of the college graduates, that 'group having a lower birth rate than any other.' There may be no need to separate alumna from the rest of her racial group for consideration, for the body of college women now is made up of nearly all the elements of what may be called the middle class. But because narrowing a subject makes it easier to view; because the birth rate of the alumnæ is the very lowest; and, especially, because I happen to know more of the conditions among college girls, I confine myself to that group.

There is no need to question the figures—that 1.8 children is the average family of an alumna wife; but let us consider in the beginning just what that 1.8 children mean. Incidentally, we may think a moment of the marriage rate among college women. Both these relatively low numbers are inspiring in one respect—in the thought of the elements which have been eliminated. If less than 50 per cent. of college women marry, yet of that number few take husbands 'for a home' or because they have nothing else to do. Perhaps there are as many happy marriages of companionship among a hundred college

women as among a hundred women selected from any class, and does the state lose by the elimination of all others?

Alumna's marriage, then, means that a mature, independent, trained woman deliberately chooses to give the direction of her life to a man, because she loves him well enough to find in so doing her greatest happiness. Of such a mating are alumna's children born—of a 'selected' father, of a mother who has at least had an opportunity for knowledge—born to a heritage of intelligent love and care. So they ought to be a power for good, even though they are few. But just because they are of such a quality, society wants more of them; and it behooves the state to determine why their numbers are so few.

Yesterday I received some evidence on this question which seemed to me pertinent. I spent the day with a member of this group 'having a lower birth rate than any other.' She had recently buried her only child, hardly a month old. As I was on my way to her, my mind went over her past year; her hope that she might at last be strong enough to bear a well child, the months of illness, the forty-eight hours of agony, the supreme joy so soon followed by anxiety, and the awful loss. And when I saw her face I could not speak. But she spoke, and with a smile: 'Don't pity me so. It paid! it pays!' During the hours I spent with her she showed me two books of letters, mostly from college friends of ours. One collection was received when her baby came, the other when he went. 'I am so happy to know that your life has been made complete'—this thought was expressed over and over again in the letters of congratulation. Mothers or childless, all these women seemed to know that any woman's life is incomplete until she has known motherhood. Of those notes that came at the little one's death from childless women, married or single, all said, in one phrase or another, 'how much sadder than yourself am I, who have no child to die.' These letters inevitably suggest the question, why are so few of these women mothers, when all of them speak of motherhood as life's greatest good? It seemed to me a very solemn question, and I went over the list of those whom I know best and found what seems to me a suggestive unanimity.

There is A, the brightest girl in our class, kept from the really brilliant literary career of which she is capable by her physical weakness. She loves a man who is her ideal mate and he returns her love, but they live their lives apart. A short time ago I said something to her about her being married. "Be married!" she said. "What right have I to be married? My physician tells me that I am no more a woman physically than is a twelve-year-old girl. What right have I to give to any man an invalid wife and take away from him his hope of children? I shall never be married!"

B has just adopted a baby, 'because I may never hope to have one

of my own,' as she wrote me. C, apparently well during college days, came to decennial the mother of three children, but such an invalid that she only with difficulty sat up during class dinner. D had one child who died at birth, and no other has ever come to her. E, an especially close friend of mine, has one child and longs for more, but her physician husband is unwilling that she should again take the risk, saying she was 'never meant to bear children.' F's case is almost the same; a woman of magnificent physique, she refused to heed her doctor. Her first baby lived, but she barely escaped herself; her second child was sacrificed to save its mother's life; 'and I can never hope for another,' she said to me, her eyes full of tears. G also would not believe her physician, but her hope was finally justified. Though three times she was disappointed, her fourth suffering gave her a son, who, she says, much more than pays for all. H has two strong, beautiful children. 'I wish we had six,' said her husband, a college dean, by the way, 'but the two that we have cost their mother so much that we shall never have any more.'

These women are all among my classmates, but the conditions are not peculiar to my class or to my college. I could cite as many instances among other college friends, but they are so nearly identical that they would seem merely a repetition. Two friends of mine now are fighting hard for the lives which have been threatened ever since their first babies came, in each case over a year ago. The example of greatest courage, perhaps, is not a college woman, though decidedly a schooled woman. Five times she went to the very gates of death for her great hope, but only once did she see the face of a living child of hers, and he died at six months.

In connection with a woman's ruling passion, I always think of that gracious lady preeminent as scholar and citizen, who recently left this world so much the poorer, especially for those who enjoyed the distinction of her friendship. I once heard a woman ask her whether she had any children. "Do you suppose," she replied, "that if I had any children, I should be running around the country talking?" And her tone said 'since all that my life seemed meant for, fails,' though all other honors were hers, save only motherhood.

Throughout my acquaintance, among not only my college friends but also my husband's college friends, I find, it has seemed to me, a large proportion of childless homes. And wherever a word has been dropped in my hearing as to the feeling of the wife in the matter, it has always been referred to as a great sorrow. I have been considering the question for some years and have tried to receive any light that appeared.

In many homes that I know there is an only child. It may seem that here are mothers who can have children but do not want them.

The only child does not mean this, but that the one came so near costing its mother her life that he to whom she is dearer than even his hope of children can not bear to let her undergo the ordeal again. Dr. Engelmann has referred to the fact that men more often than their wives wish to limit the number of their children. I shall never forget the pathos of the day when K, a boy who had graduated from college and married hardly a year before, came to tell me of the birth of his son. For twenty-four hours his wife had striven between life and death; as soon as she was out of immediate danger, he came to me, her long-time friend, and broke down. 'If this is what babies cost,' he said, 'there will never be any more at our house.' The son born that day is seven years old, but he is still an only child. I know many instances where children are few because the one or two who have come 'have cost their mother too much.'

These women are not cowards. Undoubtedly the first six hundred women who cross the campus to-morrow morning would make a Balaklava charge without a desertion. But how many men would go one by one into an advance in which they have been told there was no hope of winning and every chance of being left burdensome cripples for life? I have known many, many college women who have said, 'I *will* have my baby!' Some of them died for the faith that was in them, some of them are happy mothers; a good many are invalids, of higher or lower degree.

Occasionally we find an alumna who, not strong before maternity, is well thereafter. The stunted system develops, and she becomes the woman that she was meant to be. And what beautiful families these women have! I recall two; in one there are four children under six, in the other, five under twelve, and all hearty, beautifully brought up children.

That it is alumna's misfortune, not her fault, that her children are so few I do not expect to *prove*. The testimony for the defendant can not, in the nature of the case, be brought into court. Even were I made an accredited observer, the examples quoted could give no scientific proof, since so small a per cent. of the class has been examined. But naturally they influence my opinion because they are 100 per cent. of the cases which I happen to know all about. But I can not even say 'name and address given on application,' as the patent medicine advertisements promise.

The theory which attributes childlessness to physical weakness is by no means a new one. It has been consciously or unconsciously suggested over and over again by students of vital statistics. Dr. Holmes touches upon it in a medical address given in 1867; the declining birth rate was attracting attention even then. And again and again in discussions of the subject by students who are advancing

various theories this element in the problem appears. Among later utterances, Dr. Engelmann said, 'Race decline is not due to education, not of the educated man at least. The educated woman is in a different class.' Professor Thorndike concludes that 'the condition is due to a decrease in fertility in the racial group to which college men *and their wives* belong.' In passing we might quote another sentence of his: "The opinion of metropolitan physicians may here be as wide of the mark as the common belief that unwillingness is the cause of the failure of the women of the better class to nurse their own children."

If you grant me for a time that the cause of the 1.8—it seems like the judgment of Solomon to speak of tenths of a child!—be physical inability, what is the cause of this inability among the, let us say, schooled American women, with the rate the lowest among those who have been longest in school? What is the cause of the extirpation of that function which one would think would be of all others promoted by natural selection? Is our system of education an element in this result? These questions are surely vital in more senses than one.

Thus far I have been sure of my ground, even if I could not make it clear. Now the way is more obscure, for undoubtedly different influences operate in different classes to undermine the health of our girls. If this weakness of function appears especially among college girls, is then the college course at fault? The birth rate is only a little lower among the alumnæ, and we may find that their disability is due to conditions not directly a part of the college course, which each college woman undergoes and only nearly all other women. Observation has almost universally brought the report that the average girl improves in health during her college course.

Is then the responsibility in the high school, where the greater part of our girls do their preparatory work? Very many girls break down here, we know. Frequently a high school teacher attributes a high school boy's inaccuracy in arithmetic or his slovenly English to 'poor preparation in the grammar grades.' This may or may not be just, but I wish some one could find how much of the poor health in high school and college and during later life is due to the way in which our girls go to the grammar school.

'The way in which they go.' There is no especial fault in the content of their education, primary, secondary, collegiate or university. There is no need of making their curriculum feminine, lest womanly instincts be dulled. It is the way of taking the schooling, the physical demands of it, that have been responsible for most of the invalids that I have happened to know. Alumna's fate was sealed when she was in the grammar school.

When the bee larvæ are about a week old, you remember, it is determined whether they shall become queens or workers. It is simply

a question of nourishment; the queen has an abundance of the best food; the worker has a limited supply of inferior quality. The result is a stunting of the reproductive system of the worker bee.

May it not be possible that a similar effect comes in some degree to our women from our school system? The grammar school girl is a larva, if you please, at the age when she should develop a new system of her being, vital both to herself and to her race. To perfect these organs she needs all her rich red blood, all her nervous force. If the brain claims her whole vitality, how can there be any proper development? Just as very young children should give all their strength for some years solely to physical growth before the brain is allowed to make any considerable demands, so at this critical period in the life of the woman nothing should obstruct the right of way of this important system. A year at the least should be made especially easy for her, with neither mental nor nervous strain; and throughout the rest of her school days she should have her periodical day of rest, free from any study or overexertion. Most school girls have many unhygienic habits, all of which tend toward checking her development. Exactly these points were suggested in an editorial note in this magazine some months ago, I remember. The physical conditions and irregularities general among high school girls are appalling, in reference both to their own enjoyment and to the larger interests of the race.

But this is not an argument against our system of education in itself; the matter is not one for school boards to regulate. The intelligent fathers and mothers of our little girls of to-day are the only ones who can remedy these conditions. They can make the girl take one easy year, even though it means 'losing a grade,' that bug-a-boo of school girls; and they can keep for her her needed days of rest throughout her course. Even a year's delay in graduation is not so bad as a dwarfing of development. To hear a school girl speak to the question of her waiting a year, one would judge that existence out of her own particular class would necessarily separate her from all the desirable pupils in school. But those arguments—have you ever noticed?—are never employed when a girl is given a double promotion and advanced a class.

Losing a grade would not often be necessary, however. Ideal conditions would permit a mother to take her daughter to herself for that one year—to teach her the school work and all the other things in which she needs wise and loving instruction especially at this time, welding a companionship which will be the greatest possible barrier against future mistake and sorrow for the young woman in shaping her life.

That it is not always possible for a mother to follow this course I recognize, though it might be arranged much more often than it is if

once the mother realized what it would mean. When the mother can not do it, perhaps she can arrange for a little time of private lessons, when her daughter, working at just the rate right for her, can accomplish a term's work with a minimum of study and with none of the nervous strain which comes from competition. I can think of nothing better worth a mother's time than to establish her daughter's health for the rest of her life and make possible for her all the blessed things that womanhood may mean.

Finally, there is no doubt that some husbands and wives limit their families to one or two that they may thus do more for those few children, or have none because they can thus do more for themselves—'social ambition,' in other words. There may be to some extent a decrease in race fertility in certain racial groups without other signs of physical deterioration; yet there seems to me an amount of evidence too large to disregard which goes to show that the small families among schooled women are due to the physical weakness of the wives. Ask yourself how many really strong women you know. And while there are undoubtedly differing conditions operating in different classes and in different countries, and the contrasts between England and Germany (the birth rate is even lower for the English alumna than for the American), France and Italy, the United States and Canada, can by no means all be explained by this theory, yet I wish some investigation could be instituted to determine how much of the decrease of birth rate among native born American women comes from arrested development in our young girls—due in some classes to lack of proper food, to lack of sleep, to physical overwork, but in very many cases to their unwise manner of work and to untimely nervous strain in our grammar and high schools.

ON THE STUDY OF PHYSICS.

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THE domain of physics is coextensive with the whole range of phenomena of the material world, but the science of physics, as commonly understood, is restricted to a much smaller field whose boundaries were perhaps first marked by setting off certain groups of phenomena for special study.

In this way there arose five significant branches of physical science: (1) Astronomy, in which are treated the facts and phenomena observed in connection with the heavenly bodies. One peculiarity of astronomical phenomena is worth noting, namely, that they are entirely beyond human control and can not be made the subject of experiment. (2) Chemistry, which treats the relations of different kinds of matter one to another, and those phenomena which accompany material changes, *i. e.*, alteration in the composition of substances. (3) Biology, which deals with vital phenomena; current, as in physiology, or past, as in paleontology. (4) Meteorology, in which are grouped phenomena peculiar to the earth's atmosphere and incapable of repetition at will. (5) All the remaining natural phenomena form the subject of physics, which may be said to treat of mechanics, *i. e.*, the motion and interaction of bodies upon one another, and of those groups of phenomena commonly designated as heat, light, sound and electricity. These conventional divisions of science involve other differences not always clearly apprehended, but important alike to the student and the teacher.

While one may not say that one branch of knowledge is more worthy than another, one set of facts may be more precise or scientific than another, whatever may be the meaning attached to the word. Exactly where to draw the line between science and knowledge has been the subject of some dispute. For the purpose of the present discussion we will adopt as the definition of a science, the precise knowledge of a body of facts accurately verified and erected into a logical system. In this definition, only those branches of learning are intentionally excluded from the rank of science in which the knowledge is either ill defined, or uncertain, or unsystematized, though just what classes of historical investigation or of psychological speculation fail to meet the requirement are of no moment, as we are at present concerned only with branches of physical science. It is obvious that the branches of science thus defined may differ considerably in the precision with which the facts

may be stated and in the correlation of the parts of the system, varying all the way from mathematics, which is the science of exactness, to certain branches of natural history, which are no more than catalogues of the forms of life arranged in arbitrary classes and termed science only because they are sciences in the making, the first step always being to arrange the facts in order, even though it be an arbitrary one. Because these differences are often forgotten and sometimes ignored with consequent misapprehension and even serious error, they deserve further review and illustration.

Every science starts with a few postulates suggested by universal experience. These assumptions thus become for that particular science the ultimate things, in terms of which all its conclusions are stated, and they are not, at least as far as that science is concerned, capable of further simplification. The simplest illustration may be seen in the case of mathematics, though many of its followers do not recognize that it is a physical science at all.

Number is a common and easily distinguishable property of all bodies and of all phenomena. By the process of grouping and counting we derive the fundamental laws concerning collections of bodies, such as the associative law, the distributive law, the permutative law, etc. Having secured its fundamental data from the physical world, mathematics withdraws, so to speak, into the realm of thought and, aided by reason alone, weaves its material by successive steps into those remarkable systems which we call arithmetic, algebra, the infinitesimal calculus, the theory of functions, etc. In a sense mathematics is the most fundamental of the sciences, for without it comparisons would lose that element of exactness which alone endows them with the rank of science.

Geometry, though often reckoned as a branch of pure mathematics, is more definitely a physical science than the science of number, since it deals with extension in space, a phenomenon entirely within the domain of physics. But geometry having derived its postulates, or axioms, as they are commonly called in this connection, from experience, like the science of mathematics retires with these data into a world of abstractions; a world deprived of all realities save spatial relations and the laws of thought, and here develops a system self-contained, *i. e.*, requiring no further appeal to the physical world or to human experience.

A procedure similar to this is indeed frequently employed in the other sciences, where, having selected a few facts derived from experience, we divest them of all associations which are for the moment inconsequent, and proceed to derive by a course of reasoning, new relations which were not obvious in the premises; but there is this noteworthy difference that while in geometry and analysis the appeal

to nature is made but once and at the start, in physics new appeals to experience must often be made in the course of the reasoning, and the final relations are accepted only when they are not contradicted by the order of nature. And sometimes, even if the facts do not support the theory, it is still important to observe that the conditions of experiment may not have been so simple as the premises assumed and that the theory may still be true when the proper limitations are introduced. In the minds of certain men who are pleased to call themselves practical, a theory is exploded and to be completely rejected as soon as any discrepancy appears between the observed facts and the reasoned conclusions. To the physicist, however, some sort of theory or rational guide is so important and even necessary that a very imperfect or insufficient theory is preferable to none at all. He is not one of those who delight to hold up to ridicule false and abandoned theories, of which so many examples may be found in the history of physics, for he truly recognizes that though they now seem absurdly wrong, they nevertheless served a useful purpose as a temporary scaffold, without whose aid the more lasting structure might never have been erected. From familiar acquaintance with the imperfections of all experimental data, the physicist grows into the habit of holding his deductions subject to correction in the light of new or more accurate observations. Thus there arises the idea so well expressed by the late Professor Rowland, of degrees of truth or untruth.

> There is no such thing as absolute truth and absolute falsehood. The scientific mind should never recognize the perfect truth or the perfect falsehood of any supposed theory or observation. It should carefully weigh the chances of truth and error and grade each in its proper position along the line joining absolute truth and absolute error.
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> The ordinary crude mind has only two compartments, one for truth and one for error; indeed the contents of the two compartments are sadly mixed in most cases; the ideal scientific mind has an infinite number. Each theory or law is in its proper compartment indicating the probability of its truth. As a new fact arrives the scientist changes it from one compartment to another so as if possible to always keep it in its proper relation to truth and error.

The aim of physical science, according to the earlier writers, was the explanation of the phenomena of nature, *i. e.*, the tracing of occurrences to their causes or the proceeding by logical advance from the cause to the effect. The modern and more acceptable view, due perhaps in large measure to Kirchhoff, is that science aims to state in simple and easily reproducible language the order of the processes of nature. A phenomenon then has received its full explanation when we have presented to the mind a picture or a model in which we may reproduce at will the sequence of events which is observed in nature. All attempts beyond this to satisfy the sense of causation must be futile.

It is a well-known fact that the mind derives a certain pleasure in

tracing out similarities in very diverse things. One consequence of this process when systematically carried out was the early recognition of the fact that although the forms of nature were seemingly infinite and exceedingly complex, yet there was discernible throughout something like patterns that had been followed, as though nature were not infinitely varied after all. In anatomy, for example, the similarity in the structural form of fishes, birds and mammals was the subject of attention long before the doctrine of evolution furnished a satisfactory explanation for the resemblance.

Not less striking are the formal resemblances between the laws in widely differing departments of physics, so that, for example, if we have solved a certain problem in the distribution of heat in conductors, the same relation between the symbols furnishes the solution for an important case of electrical currents in conductors, as if the forms of the laws in nature were less complex than the phenomena, the most diversified things having been built up after exactly the same pattern.

The recognition of these far-reaching and surprising analogies is found to be most helpful. As Hertz once said, 'it seems as though an independent life and reason of its own dwelt in these mathematical formulæ; as if they were wiser than their discoverer, and gave out more than had been put into them.' But one caution is necessary. It must always be remembered that the analogies obtain between the relations and not between the things themselves. Thus we derive valuable mental assistance from the observation that electricity in its relation to potential behaves the same as an incompressible fluid with respect to pressure, but it is a great mistake to think that the thing electricity is like the thing water. Or, to take another illustration, the vibrations which give rise to the sensations of light occur with a rapidity which in an elastic solid would require an enormous rigidity; yet here, just as before, the analogy consists in the relations and not in the things, and those who try to think of an ether at once more rigid than steel and at the same time so tenuous that it produces no perceptible retardation of the planets show that they have missed the point of all analogies which is to furnish a mold in which we can cast our thought concerning the sequence of events.

In like manner, a law in science is now regarded simply as a convenient formula by which we express an observed correlation of properties or a uniformity in the order of nature, and the assumption that a law expresses a compelling and inviolate principle is wholly disclaimed.

The fundamental entities of physics, the ultimates in terms of which it is possible to express all other facts and phenomena of the science, are space, time, energy, matter, electricity and ether. It should, however, be said that it is doubtful whether there is necessity for both electricity and ether. There is a growing tendency at present to explain the properties of matter in terms of electricity.

The whole aim of the science is to state the phenomena of nature in terms of these quantities in the most exact language possible. From this point of view, a notable distinction in the kindred science of chemistry is at once apparent in that whereas chemistry introduces no new entity, it subdivides matter into upwards of eighty distinct ultimates called elements, thus enormously enlarging the number of combinations and phenomena with which it must deal.

Biology, again, while retaining all the postulates of physics and chemistry, introduces a new principle, that of life, whereby the phenomena to be treated become infinitely complex.

If we now recall that it is only the simplest phenomena of nature that can be formulated, it is at once obvious why chemistry and biology are so much more backward in their growth into exact sciences, the former being largely taken up with a description of the properties of different substances, while the latter can do little more than group together different living forms according to some principle of resemblance amid diversity. These differences make it evident that the character of mind best adapted for their investigation may differ somewhat in the different sciences, and also that the effects when taught will be more or less diverse. Different methods of presentation may likewise be found desirable.

In physics three modes of teaching are available, each of which is to be employed in conjunction with the others, each contributing an indispensable, but necessarily different and unequal, portion to the learner. They are (1) recitations upon a text-book, (2) demonstration of phenomena in lectures, (3) work in a physical laboratory. Now while there is nothing in these methods peculiar to the teaching of physics, it is important to observe that not only do the function and service of each method differ considerably in any one science, but that both the function and service of any method are widely different in different sciences. The function of the text-book is chiefly historical, *i. e.*, to record what progress in the development of the science has been effected by our predecessors; but in connection with physics it can not be too strongly emphasized that the science is not a bare record of observations upon natural phenomena. There is nothing more characteristic of the mental attitude of the physicist toward knowledge than the constant desire to answer not alone the question 'how?' but 'how much?' That is to say in other words, we begin to have adequate knowledge of a fact only when we can measure it.

A musician will say without hesitation that one composition is more classical than another. The insufficient and essentially subjective character of such knowledge is at once apparent if we press the question 'when is one composition twice as classical as another?'

Physics is not a bare record of facts, but a highly developed system

of quantitative relations between these facts and the order in which they occur. In this respect physics occupies the great middle ground between pure mathematics, in which the physical facts or axioms are few, and the principles or derived logical relations are the whole content, and chemistry in which the quantitative logical relations are few and the systematic arrangement of the facts forms the body of the science.

The discovery and the elaboration of the more important physical laws are justly reckoned among the grandest achievements of the human intellect. The character of a discovery, the persons to whom it was due, its philosophical importance, or bearing upon other parts of a science, the representation of the quantitative relations by symbols and the development of still other relations by the application of mathematical analysis, some facility in interpreting such short hand quantitative statements of physical principles, in short, the theory of physics, which is certainly the major part of this science, can best be inculcated by the use of a text-book and recitations. Surely any teaching which does not insist upon the philosophical and quantitative relations, however interesting and brilliant the experiments, or however entertaining the facts presented, or however it busies the student with laboratory exercises, does not teach the science of physics.

But granting that the theory of physics is the backbone of the science, there is no necessity of making it bare bone besides. The lectures should clothe it with flesh and blood. Physics is not an abstract science like mathematics, and the true physicist objects as much to making physics a mathematical gymnasium as he does to its appropriation as a toy for the kindergarten.

The experimental lecture affords the teacher an opportunity to present and explain to the student under the most favorable conditions the comparatively few important phenomena which he has not already met with. By favorable conditions it is meant that these unfamiliar phenomena often require the use of apparatus so delicate and costly that it is not to be trusted in the hands of any but an expert; or that the matter in question may be so overlaid and obscured by contemporaneous phenomena that the learner can recognize and follow it only with the assistance of a guide. Much also can be explained in the lectures as to the apparatus used for the determination of physical constants and the mode of conducting measurements which has no place in the ordinary text-book, and further the language may be less formal and the mode of presentation may embody much of the personal feeling and enthusiasm of the lecturer, both of which are entirely out of place in a text-book of the principles of a science. There will remain, however, a number of phenomena which, on account of their general minuteness, can not be satisfactorily exhibited in the lectures

and must be studied by the individual in the laboratory. In any elementary course they are relatively few in number, and even in a fully equipped laboratory are rarely shown to any but the most advanced students.

The value of the lecture demonstrations must again be emphasized in connection with the fact that a number of the most important phenomena, such, for example, as those of electricity, make no direct or at least no unmistakable appeal to our senses, and are apprehended only by some very ordinary occurrence like the movement of two objects in the field of vision. For example, a discovery of such immense importance as that of current induction by Faraday was evidenced to him only by the minute and momentary motion of a needle over a scale. And since throughout the whole range of physics the measurements are rarely direct, so that the interpretation of the reading of any apparatus is of more importance than making the reading, the first introduction to physical apparatus may often better be given on the lecture table than in the laboratory.

In turn with this brief discussion of the use of the text-book and the lecture demonstration the peculiar function of the physical laboratory deserves careful examination. We remark first of all that because experimental examination and dissection are essential to the teaching of biology it does not therefore follow that the laboratory teaching of physics is essential; nor because laboratory manipulation and observation are necessary to the teaching of chemistry does it follow that laboratory manipulation and observation must be necessary and indispensable to the teaching of physics. In such a statement there is not, however, intended the faintest suggestion that work in the physical laboratory is anything but useful and necessary, but rather to emphasize how widely the function of the physical laboratory differs from that of the chemical and biological laboratories. Physics is an exact science (though just what that means can be learned only in a physical laboratory) while biology is not so at all and chemistry is but to a limited degree.

Biology may be said to have formulated a few general laws, such, for example, as the law of biogenesis or the doctrine that life is generated by living beings only; the law of natural selection or the doctrine that the structure and function of any organism are the results of the survival of those members of a class which were best fitted to their surroundings; the law of prepotency which asserts that the probability of any organism approximating to its type increases with the number of its ancestors of that type. None of these laws contain any quantitative elements and consequently are never made the subject of laboratory measurements. As the rest of the science is for the most part a system of more or less rational classification of multitudinous forms of life,

or of the relation of the parts of an organism to one another there is obviously nothing in common between the observational deductions made in the biological laboratory and the quantitative measurements of the physical laboratory.

The divergence between the functions of the chemical and the physical laboratory is hardly less marked. While chemistry has irrefragable claims to designation as an exact science, the enumeration of the chief laws discovered up to the present is a simple matter and does not make a very imposing list. They are:

The law of the conservation of matter.
The law of constant proportion.
The law of multiple proportion.
The law of volumes or Avogadro's law.
The law of specific heats or the law of Dulong and Petit.
The law of periodic groups or Mendelejeff's law.
The law of electrolytic dissociation.
The law of isomerism.
The law of organic series.

It is, to say the least, a noteworthy thing that although these laws constitute the true claim of chemistry to be called a science and are moreover essentially quantitative in their character, practically no one ever thinks it necessary to the laboratory study of chemistry that students should carry out measurements looking toward even a rough verification of these laws, nor has the writer heard that the most enthusiastic advocate of the heuristic method has ever cajoled a student into thinking that he (the student) has discovered one of these laws by himself. The real fact which makes the laboratory study of chemistry a totally different one from that of physics is that the student meets even in the elementary stages a multitude of unfamiliar phenomena which can best be comprehended and learned by individual and intimate association with them, while there are altogether but two or three quantitative experiments which are available. In physics, on the other hand, the proportion is quite the reverse. The phenomena are, for the beginner, simple and entirely familiar, especially in mechanics, but the laws or quantitative relations are very numerous. Moreover, the comparisons made by the chemical student are for the most part qualitative in character; that is to say, they involve observation upon such things as the formation of precipitate, the evolution of a gas, a ready solubility or a change in color, and though the result may be more or less the particular amount is of no consequence. It is for this reason easy to arrange a laboratory course whose aim shall be to acquaint the student with such reactions, and we accordingly find him diligently employed in trying to find out what effect sulphuric acid will have on barium chloride or what silver nitrate has done to his fingers.

To spend the same amount of time in observing what happens when a brick is allowed to slide down a board or mercury is poured on a glass plate would be nonsense, and the writer of laboratory manuals feels himself driven to a verification, or study, as he may term it, of the quantitative laws. We thus too often find the student emulating Galileo in his discovery of the law of the pendulum. The absurdity of this attitude must be sufficiently obvious from the fact that in practise the student has always to be told what to discover and that it took the greatest men more than one laboratory exercise to find these laws originally.

It is at any rate true that the observation of physical phenomena for the purpose of mere acquaintance forms small part of any laboratory course, except in the more advanced parts of the subject, such, for example, as light and sound, and contrariwise those topics which demand such examination and acquaintance are commonly considered as too difficult of comprehension to be given to a beginner. From these considerations it must be evident that the usefulness of the physical laboratory can not be inferred from the benefits derived from the laboratory teaching of chemistry, but must be judged by a scale of values peculiarly its own. We have called physics an exact science. Now one of the uses of a physical laboratory is to make clear the meaning of that much misunderstood term 'exact.'

When Galileo was asked by the perplexed engineers why it was that water would not rise in their pumps to more than thirty feet he is said to have returned their question with another, 'Why does it rise at all?' To which they gave the current explanation, 'because nature abhors a vacuum.' 'Well then I suppose nature's abhorrence must cease at thirty feet' was the philosopher's doubtless knowing but evasive reply. That there is a limit to the elevation of liquids by atmospheric pressure and why is now understood by every educated person, but there are comparatively few who appreciate that exactness, like the schoolmen's *horror vacui,* ceases after a few significant figures.

The three fundamental magnitudes, time, length and mass, each possess some peculiar property in virtue of which they may be more accurately measured than almost any of the other physical magnitudes. Thus the length of the solar day is said to bear the ratio to the sidereal day of 1.00273791 to 1, an accuracy of one part in a hundred million.

The international kilogram has not been determined beyond 3/1,000 of a milligram, which implies an accuracy of one part in three hundred million.

The international meter has been measured in terms of the wave length of light to about one part in ten million, but such accuracy as that mentioned is attainable only in exceptional instances and enormously exceeds that within reach of ordinary careful work, which rarely extends to one part in ten thousand.

In the language of paradox, the physicist is exact because he knows how inexact he is. The phrase 'exact value' is a term with which many well meaning people deceive themselves and others. Every measure is imperfect. Mathematical precision is a fatuous term, except as qualified by the limits within which a statement is true.

In the face of some teaching a denial that physics is an experimental science seems almost to be justified. No law can be proved by one or by a hundred experiments. Suppose, as is sometimes done, that a student is given a bar, a knife edge and a couple of weights, and that he is asked to prove to law of the lever. He balances the bar, determines the weights, measures the lever arms and finds what? That the product of each weight by its corresponding lever arm is constant? By no means. For every time, and with whatever pains he has taken to secure accuracy, the product of the weight by its lever arm will be found different on each side, which proves, if literal interpretation of the figures is demanded, that the law of the lever is false. It is very important to recognize the fact that scientific laws are not proved by perfect corroboration of measurements. The proof of any law is of a negative character. Not even the law of gravitation nor the law of the conservation of energy is proved by any positive demonstration. The probable truth of any proposition is assumed from inability to disprove it. Whence it follows that there is nothing more fundamental to the correct understanding of the science of physics, or indeed of science in general, than the interpretation of measurements according to the theory of probabilities and a rational discussion of the inherent errors.

Now the difficult art of physical measurement can neither be taught nor learned apart from some sort of work in the physical laboratory. In this connection the student should be taught something concerning the different sorts of errors that may arise: (1) Errors of construction or of fluctuations in the measuring instruments. Many otherwise instructed people always start with the assumption that their instruments are correct. A little wholesome yet not unsettling distrust of makers' markings can be taught in a brief examination of scales and thermometers. (2) The limitations of the senses and observational errors may be clearly studied from a series of readings made upon almost any instrument having a moderate degree of sensitiveness. (3) Errors of definition, the personal equation, other constant errors and even out and out blunders demand full illustration and recognition. All these things may be taught from the simplest or from any available apparatus, and the knowledge of them is, in the writer's opinion, of more value to the apprehension of pure science than the exhibition or the so-called verification of any law that may be named.

In this insistence that the chief use of the physical laboratory is instruction in the difficult art of physical measurement, an art difficult on

the technical side, because of the patience and manipulative skill required, and difficult on the intellectual side because the comprehension of many measuring instruments is dependent upon advanced theory and considerable analytical power, it has not been forgotten that the laboratory may serve certain other though perhaps minor purposes. Just, for instance, as aid to distinct thinking may be rendered by the use of mathematical symbols and models, so also it will probably assist the unimaginative student to comprehend the laws under discussion if he can examine under his own manipulation the behavior of the apparatus which embodies those laws. Again there are certain phenomena which should be given the student for personal examination in the laboratory. Thermal phenomena involving the reading of thermometers; the passage of a liquid through the critical state; the study of compound tones; the observation of spectra, diffraction and polarization of light waves are examples of the kind of phenomena which require laboratory instruction. The number, however, of such exercises which appear even in the manuals of a college course is insignificant.

The pedagogists who, either with or without any definite knowledge of exact science, are perfectly sure how it ought to be taught assert that the first step in all good teaching is an appeal to the observing powers. "It is a cardinal principle in modern pedagogy that real and adequate knowledge of things can be obtained only in the presence of the things themselves," says one. Assuming that this is as true as the author thought it to be, it is but a half truth, the other half being that the presence merely of the things can not impart any really adequate knowledge. A boy, for instance, might watch the motion of the planets till he was gray without ever learning the first thing about gravitation or the solar system. Facts are but the raw materials of knowledge upon which the reasoning faculties must be exerted in order to extract the hidden principles of nature.

A writer of a well-known series of text-books has adopted as a sort of motto for his pupils, 'Read nature in the language of experiment.' One can not crtiticize an oracular utterance of this sort for the reason that it is not possible to say just what its author had in mind. If it is meant that empirical knowledge derived from the observation of detached facts and not brought into accordance with other facts by means of a hypothesis concerning their relation is sufficient for one to divine the laws of nature, we must certainly dissent. The language of experiment is in general a most difficult one to read, since, as we have been insisting, the measurements are in the great majority of cases indirect and to be interpreted only by tracing through a train of complex relations the consequences of the things observed upon some hypothesis whose truth it is desired to test.

Turning now to the more technical side of the science, it is interesting to notice how this indirect character of most physical measurements determines not only the mode of measurements in general, but their precision as well. A measurement, we say, consists in the comparison of any concrete quantity with a definite portion of the same physical magnitude selected as a unit. In a few instances, the comparison is direct, as in the determination of a length by a divided scale, but in the great majority of cases the numerical measure of a quantity is computed by the aid of a relation between other magnitudes which may be more directly, or, at least, more simply, measured. The content of a sphere, for instance, is not determined by successive applications of the unit-cube to the enclosed space, but by first measuring its diameter with calipers and then calculating the volume by the known geometrical relation between the two. Or, to cite another illustration, the direct comparison of a given velocity with the assumed unit of velocity would be a troublesome thing, involving, if they were not very nearly equal in amount, the repeated subdivision of the one or the multiplication of the other. To avoid this, we define the measure of velocity to be the distance traversed per second, and the measurement may then be effected by the simpler process of measuring separately a distance and a time.

In making comparisons, one of the senses must ultimately be appealed to as the judge of the coincidence of two values, but in forming this judgment apparatus is introduced of such sort that the comparison shall contain the least amount of personal bias or subjective impression, thus eliminating as far as possible the psychological element, since the thing desired is a physical equality rather than a psychological one. The former must indeed involve some form of the latter, but equal psychological impressions do not entail equivalent causes. It is a remarkable fact that practically all exact measurements have been reduced to the judgment of the coincidence of two lines by the sense of sight. This universal preference of the eye is probably due not so much to the greater freedom of this sense from illusive deception, as to its unique relation to geometrical space. Various of the other senses are able to distinguish and even to compare degrees or amounts of differences in the sensations peculiar to them, *i. e.*, they are able to estimate a kind of interval or difference in these sensations. The ear in connection with memory, is able to distinguish an interval of time between two successive taps as small as one one hundredth of a second, which is perhaps ten times as well as the eye can do with successive flashes. In another kind of sensation peculiar to hearing, namely pitch, the ear without the aid of beats easily distinguishes sounds whose frequencies are in a smaller ratio than 25/24. Similarly the muscular sense will under proper conditions distinguish an increase in weight of

about one per cent., and it is said that experts can distinguish the difference of a fraction of a degree centigrade by the temperature sense alone. Now while the other senses may distinguish two or more kinds of extension, as, for instance, pitch and loudness in the case of hearing, vision is the only sense with quantitative perception in which the extensions are identical in every respect except in their relation to directions, thus giving a field of vision so-called within which individually different marks may be compared. The eye is capable of judging the coincidence of two abutting lines to one minute of arc, which is a more sensitive determination than can be secured from any other sense perception.

The preceding pages may have conveyed the impression that the study of physics is a stern and difficult one. While there was no wish on the writer's part to magnify the difficulties of this most interesting science, it was a definite part of his plan to show that the proper teaching of physics does not consist in the acquisition by the pupil of first-hand knowledge of phenomena; neither does it consist in trying to implant a spirit of inductive reasoning whereby a student is led to divine the great laws of nature as a discoverer; least of all is the obedient following of directions set down in a manual or given by an instructor the study of physics. That alone is true and successful study which cultivates logical power in dealing with phenomena, gives a tenacious hold upon what is known and adds at least something of how the field in present possession of the science was explored and occupied.

ENGLISH HERBALS.

By AGNES ROBERTSON, B. Sc.,
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IN the fifteenth and sixteenth centuries there was a renewal of the scientific spirit, as well as the more obvious revival in art and letters of which we commonly speak as the Renaissance. Among the most striking of the many visible fruits of this revival were numerous herbals, in which all the plants then known were enumerated, described and often beautifully figured. The earliest English example with which I am acquainted is a small, black-letter, anonymous volume published in 1525. The title is 'Here begynneth a newe mater, the whiche sheweth and treateth of ye vertues and propeytes of herbes, the whiche is called an Herball.' There are scarcely any descriptions of the plants, but long and elaborate dissertations on their virtues. Even such a commonplace weed as the plantain is credited with considerable powers: "For heed ache take Plantayne and bynde it aboute thy necke and ye ache shall go out of thy heed." Of rosemary we read: "Take the flowres and make powder thereof and bynde it to the ryght arme in a lynen clothe, and it shall make thee lyght and mery. Also boyle the leves in whyte wyne and washe thy face therwith, and thou shall have a fayre face. Also put the leves under thy beddes heed, and thou shal be delyvered of all evyll dremes. Also make thee a box of the wood and smell to it, and it shall preserve thy youthe."

In the following year was published one of the most famous of the old herbals, 'The Grete Herball which geveth parfyt knowlege and understandyng of all maner of herbes and there gracyous vertues.' This includes in addition to plants, descriptions of a number of substances, such as gold, silver, asphalt, starch, vinegar, butter, honey and the lodestone! It contains delightful prescriptions for healing all manner of ailments. For instance, Apium 'is good for lunatyke folke yf it be bounde to the pacyentes heed with a lynen clothe dyed reed the moone beynge in cresaunt in the sygne of Taurus or Scorpion in ye fyrst parte of the sygne, and he shal be hole anone'; and as a cure 'for werynesse' we read, "To them that be wery of goynge gyve to drink a dragme of the powdre of Bethony with warm water and an once of orimell." The following statement gives an inkling of the condition of plant-geography at the time: Balsam 'is founde towarde Babylon, in a field whereas VII welles or fountaynes be, and is carried from thens'!

Nearly thirty years later, Henry Lyte translated into English the famous Dutch 'Herbal' of Dodoens. Lyte was an Oxford student who traveled in foreign lands and collected a number of rare plants, and on his return to England founded one of the first botanical gardens in this country. The title of his translation is 'A niewe Herball, or Historie of Plantes: wherein is contayned the whole discourse and perfect description of all sortes of Herbes and Plantes; their divers and sundry kindes: their straunge Figures, Fashions, and Shapes: their Names, Natures, Operations, and Vertues.' The book is most beautifully illustrated, and contains the records of some capital pieces of observation, but it is startling every now and then to meet with statements like this, 'Alysson hanged in the house, or at the gate, or entry, keepeth both man and beast from enchantments, or witching,' and 'The seede of the garden Larckes spurre dronken is very good agaynst the stinging of Scorpions, and indeede his virtue is so great against their poyson, that the herbe throwen before the Scorpions, doth cause them to be without force or power to do hurte, so that they may not move or sturre, until this herbe be taken from them.'

At the very end of the sixteenth century appeared the best known of all the herbals, that of 'John Gerarde, of London, Master in Chirurgerie.' Gerarde seems to have been an unscrupulous plagiarist, for he bases his herbal, quite without acknowledgment, on Priest's translation of Dodoens's collected works. Also of his eighteen hundred wood-cuts, less than twenty are original! So, altogether, his great reputation seems to have been built on somewhat frail foundations. Still he appears to have been a first-rate botanist, and in his garden in Holborn he cultivated more than a thousand different kinds of plants. I can not help thinking how delighted he would have been with a modern botanic garden, and particularly with one of the modern collections of insectivorous plants. For he gives a little figure of Sarracenia, the pitcher plant, copied from Clusius, who says he received the drawing with one dried leaf from an apothecary of Paris, who himself received it from Lisbon. Gerarde reproduces the figure 'for the strangeness thereof,' and in the 'hope that some or other that travell into forraine parts may finde this elegant plant, and know it by this small expression, and bring it home with them, that so we may come to a perfecter knowledge thereof.'

Later on the fashion set in of leavening botany with astrology. The best known exponents of this kind of pseudo-science are Culpeper and Turner. Nicholas Culpeper seems to have been afflicted with boundless self-conceit; the following is a sample of his bombastic style: "To find out the Reason of the operation of Herbs, Plants, etc., by the Stars went I, and herein I could find but few Authors, but those as full of nonsense and contradiction as an egg is full of meat; this not being pleasing, and less profitable to me, I consulted with my two Brothers, Dr. Reason, and Dr. Experience, and took a voyage to visit

my Mother Nature, by whose advice, together with the help of Dr. Diligence, I at last obtained my desire, and being warned by Mr. Honesty, a stranger in our days, to publish it to the World, I have done it." Culpeper seems to have been absolutely saturated with his astrological notions; he tells us that 'seed sowed at the wane of the Moon, grows either not at all, or to no purpose'!

Returning to the earliest herbals, we find that the idea of natural relationship between plants, or even of the necessity of any sort of classification, is scarcely existent. The anonymous Herbal of 1525, and the 'Grete Herball' are both arranged alphabetically. But the 'Grete Herball' contains the germ of a classification of the fungi—a classification of the most charming simplicity! "Fungi ben musherons. There be two maners of them, one maner is deadly and sleeth them that eateth of them, and be called todestoles, and the other dooth not." Exactly fifty years after the publication of the 'Grete Herball,' Lobel's 'Herbal' appeared, and from it we gather that during this half century the idea of natural affinity had been in a sort of dim instinctive fashion getting hold of men's minds. He describes in succession rushes, grasses, bulbous plants, orchidaceous plants, crucifers, composite plants, etc. The arrangements adopted by Dodoens and later by Gerarde are similar to that of Lobel, but slightly more natural. Parkinson in 1640 gives a more elaborate classification, and though it seems very primitive when judged by the standard of the present day, especially as regards the stress laid on the 'virtues' of the plants, yet it shows that great progress had been made since the publication of the earliest herbals. He divides all plants into seventeen classes, some of which are quite satisfactory, while others, such as No. 14, which includes 'Marsh, Water and Sea Plants, and Mosses and Mushrooms,' are a trifle too comprehensive! There is something charmingly naïve about the titles of his fifteenth and seventeenth classes. These are 'The Unordered Tribe' and 'Strange and Outlandish Plants.'

Early in the next century Linnæus was born. A vast mass of information had been accumulating for two hundred years, and it needed a luminous intellect like his to reduce it to order. As the fruit of his labor we have his marvelous 'System,' in which he followed a much earlier writer, the Italian botanist, Cesalpinus, in attributing the chief importance to the organs of fructification. The day of the herbal proper may be said to have closed with Linnæus and thenceforward botany proceeded on more strictly scientific lines. The subject sprang into fashion in his time in the most astonishing way, probably owing to the easy method which his 'System' offered of tracking down and identifying plants—from the chosen pursuit of a few enthusiasts it became the heritage of the many—it was dubbed the 'loveliest of the sciences,' and 'recommended especially to ladies, as a harmless pastime, not overtaxing to the mind.'

THE GEOLOGY AND GEO-BOTANY OF ASIA.*

By PRINCE P. KROPOTKIN.

THE time has not yet come when the geological history of Asia can be written in full. It appears, however, that, with the exception of a marginal zone in the south, which belongs to the Himalayan upheavals, the great plateaus of east Asia are built up of crystalline unstratified rocks, granites, granitites, syenites and diorites, as well as of gneisses, talc and mica-schists, clay-slates and limestones, which all belong to the Archean formation (Huronian, Laurentian, Silurian and partly Devonian). They thus can not have been submerged by the sea since the Devonian epoch. The higher terrace of the plateau of Pamir and the plateaus of the Selenga and the Vitim are formed only of Huronian and Laurentian azoic schists; even Silurian deposits—widely spread on the plains—are doubtful on the plateaus. Their upheaval must date accordingly from an earlier age, and they must have been a continent during the Devonian epoch, while parts at least of the lower terrace were under the sea at that period. During the Jurassic and Tertiary periods immense fresh-water basins covered the surface of those plateaus; they have left their traces in Jurassic coal-beds, and in Tertiary sands and conglomerates, these latter appearing in mighty layers on the borders and slopes of the plateaus. The chains of mountains which fringe the plateaus along their northwestern and southeastern borders are of the same ancient geological origin. They rose above the Carboniferous, Triassic, Chalk and Jurassic seas which covered what are now the lowlands and lower terraces of Asia; the upheaval of these chains has, however, continued throughout these epochs, so that in the outer chains of Asia we see Carboniferous and younger deposits, up to Tertiary, lifted up to great heights. The same is true of the border-ranges along the southwestern border of the great plateau of east Asia, namely, the Himalayas, which were lifted during the Tertiary age, while at their northern foot, on the surface of what is now the surface of the plateau, traces of Triassic deposits seem to have been found near Lhasa. Carboniferous deposits are met with in Turkestan, India and western Asia; while in eastern Asia the numerous coal-beds of Manchuria, China and the archipelagoes are all Jurassic. As to the age of the plateaus of western Asia, it remains unknown at the present time.

* From an article in the March number of *The Geographical Journal.*

What are now the lowlands of Asia must have been widely submerged by the seas of the Tertiary period, as also those of the Quaternary (Post-Pliocene) period. During this last period, the whole of the lowlands of northwest Siberia were under the sea, as far as the fiftieth degree of latitude, a broad gulf of the Arctic Ocean penetrating at the eastern foot of the Urals as far as the watershed which now separates the basin of the Obi from the Aral-Caspian Sea. At the same time there are no traces of that sea on the high plains of east Siberia, which were only intersected by several narrow elongated gulfs of the ocean. The moistness that thus ensued permitted glaciers (which are wanting now throughout the middle parts of east Siberia and Mongolia) freely to accumulate, so that the whole of the upper plateau and its border-ridges were under a mighty ice-cap. Immense glaciers, like those of the Alps and Jura, covered also the alpine regions. How far glaciation extended over the plateau of Tibet and in China still remains unsettled. In Turkestan and Siberia immense accumulations of loess fringe the alpine regions; while in China they cover immense tracts, and are the most fertile regions of Asia.

Many important changes in the distribution of land and water have been going on in Asia since the Glacial period, and even during historical times. Since the Aral-Caspian Sea became isolated from the ocean, its desiccation, as well as that of the numberless lakes which dotted the surface of Asia during the Lacustrine (Post-Glacial) period, has proceeded with a rapidity which may be guessed from the very rapid rate at which the process has been observed to go on in Siberia during the last hundred years. All Asia bears unmistakable traces of having been covered during the Lacustrine period with numberless large and small lakes, which have now disappeared, not in consequence of the action of man, but in consequence of some general causes affecting the earth's surface since the last Glacial period. The process is still more accelerated by the rapid upheaval of the continent—the whole of the Arctic coast, as also most of that washed by the Pacific, the Mediterranean, the Red Sea and parts of the Indian Ocean, being in a state of gradual elevation, while the few areas where traces of subsidence have been noticed are very limited. The influence of the desiccation of Asia has been felt even during historical times, and the migrations of the Ural-Altaians, Turks and Mongols will probably be best explained if this change in the condition of central Asia be taken into account; while the same circumstance explains the present nearly desert state of those regions which were the cradle of European civilization.

Volcanoes play an important part in Asia's geology; no less than 122 active volcanoes are already known in Asia, chiefly in the islands of southeast Asia, the Philippines, Japan, the Kuriles and Kamchatka,

as also in a few islands of the Bay of Bengal and Arabia, and of western Asia. Numerous extinct volcanoes are found, not only in the same regions, but also in the Caucasus, on the plateau of Armenia, in east Tian-shan, in the northwestern border-ridges of the high Siberian plateau, and in the southwest of Aigun, in Manchuria (the Uyun Holdontsi region). An immense zone of land was covered with basaltic lavas during the early Tertiary period (or Cretaceous?) along the northwestern border of the high plateau of east Asia, and vents through which scoriæ were ejected, forming small cones of ejection, are still seen on the Mongolian and Vitim plateaus, as well as in the Sayans. Earthquakes are frequent, especially in Armenia, Turkestan and around Lake Baikal.

With the rich botanic materials which we are already in possession of, it would be extremely interesting to make a picture of the distribution of the different floras of Asia upon the surfaces of its high and lower plateaus, their border-ranges, the alpine zones, the high plains, and the lowlands. It would then appear how much these orographical divisions can help us to find out the true distribution of floras, which botanists have hitherto tried to bring into accordance with zones that were traced either along the degrees of latitude, or according to the basins of the different rivers, without taking into account the great orographical divisions and the differences of altitude, which mostly run in diagonal directions. Thus, to take only one example, the Great Khingan is the most important botanical boundary which is found all over Siberia and Manchuria. When one crosses this border-range and goes down its steep slope towards the east, one sees that in one hour, or maybe in half an hour, quite a new flora—Manchurian—takes the place of the Siberian flora; and one notices the appearance of trees, which strike even the most ignorant in botany, because these trees have not been seen before, while the traveler crossed Siberia over a distance of several thousand miles. One sees also how the Manchurian flora endeavors to spread westwards along the valleys of the Upper Amur and the Argun. Another important botanic boundary is the escarpment of the upper plateau, that is, the border-range of the Yablonovoi. This escarpment separates the Daurian flora from the Siberian, properly speaking, as sharply as the Great Khingan separates the Manchurian flora from the Daurian.

The Little Khingan will, I am inclined to think, also appear some day as another interesting botanic boundary between the Manchurian flora and the flora of the Pacific littoral. It is also quite certain that in central Asia, in the Gobi, in India and in western Asia, one could arrive at most interesting botanical generalizations by establishing the connection between the orographical and the botanical data; it is sufficient to mention here, as an instance, the delimitation of botanic

regions in the Caucasus lately made by Russian botanists, who have shown that the Pontic range (that is, the border-range of the Armenian plateau) is an extremely important botanic boundary, or the remarks of M. Novitskiy concerning the flora of the Karakoram plateau.

The immense region which is usually represented on geo-botanic maps under the name of Eur-Asian boreal region, and which is bounded on the south by a line traced from the Black Sea to Lake Baikal and thence to the Upper Amur and to the Sea of Okhotsk—this region has not the uniformity which one would be inclined to attribute to it by considering the map only. While it is quite certain that plants easily spread from west to east—from Russia to the lowlands of western Siberia—they spread also with the same facility from the southwest to the northeast along the high plains, the alpine zone, the border-ranges and the plateau itself. Consequently, the flora of Siberia itself can already be subdivided quite naturally into a number of distinct regions running southwest to northeast, and not west to east. Thus we see, for instance, the cedar-tree (*Pinus Cembra*) spreading along the highest parts of the northwestern border-range of the high plateau, from the Altai to the Lena. We find again the same vegetation on the high plateau in northwestern Mongolia, round Lake Kosogol and the Upper Vitim. The vegetation of the high plains of the Altai offers again a great analogy with the vegetation of the high plains in the west of Lake Baikal (the Minusinsk flora being an intermediate link between the two), and the Transbaikalian flora in the east of the Yablonovoi has very much in common with the flora of the Gobi.

As soon as the Amur emerges from the high plateau, in which it has excavated a deep valley, we find on its banks representatives of the Chinese and Japanese flora under the very same latitudes where we find the Siberian flora further west. And it appears from recent explorations that even round Lake Balkhash, and at the foot of the Tian-shan, vestiges of the European-Siberian flora have maintained themselves on the best-watered slopes. The lines of propagation of plants along the degrees of latitude are thus completed by lines of propagation having an oblique direction, from southwest to northeast.

The next zone which is marked on our botanical maps is the zone of the Steppes, which spreads from the prairies of south Russia through the Aral-Caspian depression and the middle parts of the high plateaus.

Western and eastern Asia, including various separate desert regions (the Han-hai, the Gobi, the dry parts of Inner Arabia, of Persia and of northwest India). However, this immense region ought to be subdivided, for central Asia alone, into at least four distinct regions, namely, the Aral-Caspian flora, the Tian-shan, the Tibet and the Mongolian flora.

The flora of the regions situated on the east of the high plateau,

including China, Manchuria and Japan, must be considered as a counterpart of the Mediterranean flora. The oak reappears as soon as we cross the eastern border-ridge of the plateau, which is the Great Khingan; so also the walnut tree, the lime tree, the hazel and the myrtle, while several new species of poplar, willow, acacias and many others make their appearance. The forests, consisting of a very mixed vegetation, where southern species meet with northern ones, become really beautiful; while in Japan a variety of species of pine and the reappearance of the beech add to their beauty. A rich underwood of lianas, ivies, wild vines, roses and so on renders the forests quite impassable, especially in the littoral region, which is submitted to the influence of the monsoons. In the lower parts rich prairies cover immense spaces, the grass vegetation becomes luxuriant, and in the virgin prairies of the Amur man and horse are easily concealed by the grasses of gigantic size. Rice and cotton are cultivated in the southern part of the region. However, this region is too vast, and has too many different aspects, to be considered as one single region, and ought to be subdivided into three sections—the Chinese flora, that of Manchuria and the Okhotsk littoral.

A striking change in the character of the vegetation is also seen, as we now learn from recent exploration, at the southeastern extremity of the high plateau of Asia. The traveler who comes from Mongolia and has crossed the Kam region of eastern Tibet finds, as soon as he has penetrated into the region of the tributaries of the Blue River and Mekong, quite a new world, both vegetable and animal. The very fact that the 12,000-feet-high plateau is deeply excavated by the valleys and canyons of the great rivers, and that this part of the plateau is submitted to the influence of the monsoons blowing from the southwest, is sufficient to give quite a new character to the vegetation, which may be described as a mixture of the Chinese and Indo-Chinese floras.

In the Caucasus the rich vegetation of the wet portions of the country, situated between the main chains of the Caucasus and the Pontic chain, belongs to the Mediterranean flora of western Europe. As to the flora of Asia Minor, it combines the species of southern Europe with those of north Africa, as we find there evergreen oaks, the laurel-olive tree, the myrtle, the oleander, the pistachio tree and a great variety of bulbous plants.

These few remarks indicate how much the task of the geo-botanist would be facilitated if he took into consideration the great features of the orography of Asia and the orientation of the main orographic divisions. The same must be said with regard to the fauna of Asia. It would be impossible to understand its distribution if we did not take into consideration, as has been indicated by Syevertsoff, the spreading of many species from the southwest to the northeast along the plateaus

and the plains. It may thus be said that the high plateau of Asia has its own fauna, so also its lower terrace, and also the lowlands of the deserts and those of the prairies.

* * *

If the theory of Dana is approximately correct, then the gradual growth of the Asiatic continent, as well as its present shape, can be very well explained. During the Primary epoch, Asia consisted only of the high plateau, which had the shape of a South America, directed by its narrow point towards the Behring Strait. (Was not the North Pole in that direction at that time?) On the line of division between what was then the continent and the oceans which surrounded it at that time, in consequence of the oblique thrust of which Dana speaks, the border-ranges must have been formed all along the fringe of the high plateaus, while a succession of parallel mountain ranges, resulting from as many foldings of the strata, were formed round the continent, just as the islands of Formosa, Japan, and so on, are now lifted all round the continent of Asia in a series of curves indicated by Suess. Later on, when the lower Mongolian terrace of the plateau emerged in its turn from the ocean, the formation of mountains was continued along its borders. It was then that, in all probability, the border-ranges of the second terrace (Great Khingan, etc.) and the alpine zone which fringes these border-ranges were formed.

A similar formation is also found, but on a much smaller scale, along the fringe of the third terrace—the terrace of the high plains; but the arrest of upheavals was not sufficiently long at this stage, nor was the difference of level between the high plains and the bottom of the ocean sufficiently large to generate the high border-ranges such as we find along the fringes of the plateau. And finally, during the recent periods, a series of littoral chains has been lifted up, and is being lifted up still, all along the present coasts of the Pacific Ocean. That these chains are not generated in straight lines, but have a crescent shape, as has been suggested by Suess, is pretty correct, and it must also be remarked that the border-ranges of the plateau also are not quite straight lines. We see, on the contrary, that straight lines are intermingled with crescents, and when I speak of chains of mountains having a direction from the southwest to the northeast, or from southeast to northwest, I only mean that such is the general direction of the chain, without pretending to say that the chain follows necessarily a straight line. Sometimes the line is nearly straight, or it follows a great circle of our globe; this last case is very frequent, but sometimes it also has the shape of a curve. It thus appears that the theory of Dana, completed by the study of erosions which took place during an extremely long succession of ages on a grand scale, and the generalizations concerning the orography of Asia, which are expounded here, stand sufficiently in accordance for mutually confirming each other.

THE ROYAL PRUSSIAN ACADEMY OF SCIENCE AND THE FINE ARTS. BERLIN.

By EDWARD F. WILLIAMS,
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III. From the death of Frederick the Great to the death of Frederick William III., 1786–1812.

NOTHING was of more importance to the academy during this period than its change from a French to a German institution. This change was brought about in part under Frederick William II. (1786–1797) by his minister Hertzberg who had long been a member of the academy, and who under the new king became its curator and so remained till his death in 1795. The change was made complete, in form at least, by the adoption, in 1812, of what is known as the Humboldt brothers' statute. At this time the academy was ruled by a new spirit. It was under the control of men like the Humboldts, Niebuhr and Schleiermacher, who sought to realize through it the aims of Leibniz, its founder. The new spirit was manifest in all its departments; in those of philosophy, history and philology, as well as in those of science. Together with a growing respect for the ability of German writers and thinkers there was an increasing love for the fatherland, a conviction that patriotism was as worthy of cultivation as the new fields of learning which were opening on every side.

Hertzberg, though somewhat arbitrary in his methods, saved the academy from threatened dissolution. He was in many respects a very remarkable man. As a statesman he sought to carry out the views of Frederick the Great. A true son of his century, a scholar of no mean rank, skillful as a historical student in the use of original documents and deeply interested in the work of the academy, he determined to reorganize it on the basis of the old German spirit. If he cared little for Goethe and his cosmopolitanism and failed to appreciate Herder at his true worth, he did not fail to see what an opportunity the academy might have for directing the thought and life of the German people. In his hands the curatorship became an office of power. In order to weaken French influence in the academy during his first year as curator he added fifteen Germans to its eighteen active members, and secured for foreign membership men of the first rank like Gasse of Breslau, Eberhard of Halle, Kant of Königsberg, Magellan, Volta, Wieland, Heyne and Herder. His only mistake was in not bringing these men to Berlin and associating them with the resident German element

in the work of the academy. If the French element regretted its loss of power in the academy, it made the best of it and continued to contribute to its publications. Ceasing to be minister in 1791, Hertzberg continued to work for the academy until his death. In some of his political views he was a liberal, and in papers read at the regular sessions of the academy, and afterwards printed, he did not hesitate to compare the advantages and disadvantages of monarchical and republican forms of government. After the French Revolution it is not strange that kings and their sympathizers became suspicious of his opinions. Subsequent to his death, during the remainder of the king's life the academy did very little. In this reign only three volumes of 'Memoires' were published. In 1795 the French language was again made the medium of discussion in the academy. It was voted also that for five years no new members should be received. Alexander von Humboldt characterized it as 'a hospital in which the sick slept better than the well.' For the indifference of the German members there is little excuse. They were silent when they ought to have spoken, cowardly when they should have been brave. Greatly indebted to Hertzberg for the influence he had exerted in the days of his power on behalf of the academy, its members took no notice of his death, nor made any reference to him in official publications. It sank so low as to countersign an order of the cabinet against Kant, and ceased to be a center for free thought and free speech. It seemed to be more at home in exercising the duties of censorship than in increasing and diffusing knowledge. It is not strange that men who sympathized with Mendelssohn united with him in organizing the Philosophical Society, which soon became a center for the new thought and life of the time, where men who cared to discuss questions of the day could meet in safety. From 1783 to 1798 this society filled a great place in the Prussian capital.

Under Frederick William III. the academy was managed by the Humboldts and Niebuhr. At the beginning of his reign the new king was supposed to be in favor of progress and freedom in thought and speech. But after his first year on the throne he became a reactionary, and was not unwilling to exercise his prerogative as censor. He wished the academy to confine itself to studies and investigations which would be of use to the nation. Neither he nor any of his ministers would aid it on other conditions. The cultus minister desired its assistance in improving the public schools. There were protests against the old rules introduced by Hertzberg. An order of April 9, 1798, cut deep into the life and privileges of the academy. The presidential office was left vacant. Only such work as was of immediate advantage to the people was approved. Borgstede was put into the academy by the king, as his representative and to look after its interests. Fortunately he had a real desire for the growth of the academy and did what he could for

it. Its membership was reduced by order of the king to six and a director for each of the four classes, or twenty-eight in all. From 1799 to 1806 there were no important changes in either the constitution or the by-laws of the academy. But while wars were waging and political storms were brewing its members led a quiet and peaceful life and made some contributions of real value to the learning of the world. The French Academy at this time was far in advance of that in Berlin in scientific work.

But there were thoughts of a university in Berlin even in the dark days of the French invasion, and as early as 1800. The observatory was rebuilt at the expense of the academy. Wulff of Halle was induced to come to Berlin and work in it. In 1800 Humboldt, then absent in South America, was made an honorary member, and on his return to Berlin in 1805 he became an active member. Kotzebue was received in 1800, and Thaer was induced to leave Hannover for Berlin in order that he might join the physical class of the academy. He was the author of a system of law which proved of great value for Prussia. Professor Thalles of Bonn, a famous mathematician, was also brought to Berlin and received into the academy. As early at 1788 Johannes von Müller, the well-known historical writer, became a foreign member, though afterwards he made friends with Napoleon and turned his back on his country. Perhaps it was on account of aversion to philosophical opinions which their author deemed epoch-making, as well as to dislike of the man, that Fichte, though brought forward by very influential persons, was rejected as a member of the academy. But he was permitted to deliver his lectures in the winter of 1804–5 in its hall. These lectures were a kind of negative preface to the 'Reden,' or addresses to the German people, made a year or so later, which did so much to arouse and unite them in their struggle for liberty. Alexander von Humboldt proposed and secured the election of Ermann, the physicist, and of von Busch, the geologist, as extraordinary members of the academy. Not long after Buttmann, the grammarian, became an active member, and with him, by order of the king, Count Lahndorff, the poet. Before the war began on July 31, 1806, *i. e.*, prior to the disaster at Jena, Goethe, Cuvier, Brooks and Hendenberg were made honorary members.

The proceedings of the academy the next six years were fundamental for its future life and activity. In the two Humboldts it seemed as if the spirit of Leibniz had revived, as if they possessed his extensive general knowledge, his love for the sciences, his power of organization, his leadership and his ability to meet and overcome difficulties. There were other able men in the academy, but at this time the two Humboldts were its leaders. The defeated king was at Königsberg, whence he made known his wish that Prussia seek to recover what had been

lost materially through improvement in methods of education and a deeper and truer spiritual life. Neither he nor his advisers would admit that there was no future for their suffering country. In spite of losses of territory and of the choicest specimens of art and sculpture in the museums, in spite of the fact that even the academy had been robbed of its most valuable treasures, it was in this period that the University of Berlin was founded and men of the highest attainments obtained as professors and also as members of the academy. King and people seemed to be determined to prove to the world that the spirit and pride of Frederick the Great still ruled the Prussian heart. There were some who desired a union of the university and the academy, but of this plan the king did not approve, although he was not averse to a very close connection between them. So far as they had ability for it, he wished professors to work in the academy as well as in the university.

Upon the whole, the king favored the academy, and although he did not relieve it as it requested from the burden of Lambert's presidency, he gave it the four secretaries it asked for, one for each class, and allowed them to direct its work. Before the royal decree establishing the university had been issued, Schleiermacher, Wulff, Schmalz and Fichte, through their lectures, had really laid its foundations and begun its work. At about this time (1810) Alexander von Humboldt proposed a good many changes in the constitution and rules of the academy, most of which were adopted. These changes sought to promote equality among the members and favored the reception of men of high attainments rather than of large wealth or political influence. All the desired changes, however, were not adopted until they were incorporated in the constitution of 1812.

William von Humboldt became an honorary member of the academy in 1806, when he was serving the government as ambassador in Rome, and an active member in 1810. His entrance speech, limited to a few words, is said by those who heard it to have been delivered in such words as he only could use. As minister of instruction he had rare opportunity, which he did not fail to embrace, to work for the interests of the academy. It needed all the aid he could give. Financially it was in great straits. Although Napoleon offered to send plaster casts of the objects of art the French army had carried away, there was no money with which to pay the cost of transportation. Expenses as planned by its members would have been nearly $25,000 a year. The request for a grant to this amount, though some of the older members looked grave and shook their heads, was not at all extravagant, considering the salaries the academy had to pay and the fact that it had to provide for the support of the library, the observatory, the botanic garden, the scientific collections, the care of the buildings, as well as to meet many unexpected miscellaneous expenses. At this time it was

asked to turn over to the government the 'Calendar' monopoly it had so long enjoyed. This it was not inclined to do until the order of the king rendered it imperative.

In 1811 William von Humboldt was sent as ambassador to Vienna, but his views and plans for the academy were left with his friend Nocolovinus, who secured their adoption and their incorporation into the constitution and by-laws of 1812. This was the last year in which the reports of the academy appear in French. The income actually obtained was a little less than $7,000, but the expenses of the institutions which it had previously met were now met from other funds. The new statute was confirmed by the king on January 24, 1812, and the next year the last volume of the 'Memoires,' bearing the date of 1804, was published. In offering prizes Latin and French were still used, but henceforward the language of the academy, for its publications as well as its discussions, was German.

In its management there was now neither president, curator, nor director. The management of its work was in the hands of four secretaries. There were the usual classes of members, active, foreign or honorary, and corresponding. It was decided that only twenty-four foreign members should be chosen, eight for each of the scientific classes and four for each of the other two classes. There was no limit to the number of corresponding members. Regular sessions were henceforth held every Thursday afternoon, and every fourth Monday each class had an extra meeting in order to render its special work more effective. There were to be three public meetings each year, one of them in July in honor of Leibniz, another on the king's birthday, the third on January 24, or Frederick's day. Each member was required to read at least one paper every year until he had been in the academy twenty-five years; after that time, at his own pleasure. The subjects were to be assigned by the class to which the member who was to write belonged. Each class was permitted to choose its own members, subject to the approval of the entire academy and of the king. Each volume of the proceedings or transactions, was to be divided into four parts, so that reports of the work of each class might appear together.

In 1811–12 twenty-four foreign members were chosen, among them William von Humboldt, now residing in Vienna, Jacobi, the philosopher, and Professor Dugald Stewart of Edinburgh. There were twenty-one honorary members and ninety corresponding members, forty-eight of them in the scientific classes. More than half the entire number was German. Up to this time the academy had given more attention to reports of what had been done by others than to original research and the diffusion of knowledge. In scientific work it was at least a generation behind the academies of England, France and Sweden. All this was now changed. Under the new order each secretary became in a

measure responsible for the work of his class, the nature and amount of which he determined. In addition to presiding at the meetings of his own class, each secretary in turn presided for a period of three months at the general meetings of the academy. Treatises receiving the prize were regarded as the property of the academy and those deemed worthy of favorable mention could be printed by it if it desired. But no paper could be printed except by a two thirds' vote of the whole academy. Out of the income of $7,000, the sum of $650 was set aside for emergencies and $700 for scientific purposes. Though cramped for means the academy was now better organized than ever. It had proved its right to live. In fact it had made a place for itself among the learned societies of the world. It had gained the respect and confidence of German scholars and was beginning to enjoy, as it had done in the time of Frederick the Great, the favor of the reigning sovereign and of his ministers of state. How this had gradually been done will be seen in a brief account of the work accomplished during the period under review.

This consisted to a very large extent in offering prizes and in deciding upon the merits of the treatises which these offers secured. The subjects discussed indicate the thought of the period. But the academy did more than read learned papers and determine their respective merits. In the sentiment it created, and by means of the topics it selected for consideration, it directed the thought of the time. Some of these topics may here be given. In 1786–87 the question to be answered was 'shall the mythology of the Greeks and the Romans be retained in modern poems, or that oldest German and northern doctrine of the gods, or the miracles of the Christian religion?' Such a question indicates unrest and dissatisfaction in the minds of some of the older poets of the time. Four years later Gedike asked the academy, 'what reason is there in the present condition of learning to look upon the ancient languages as the foundation of a liberal education, and would it be advantageous or disadvantageous for science to treat them no longer as a part of official instruction, but confine their study to a limited class of scholars?' Teachers, it was agreed by all, must learn them, but there were many, then as now, who doubted the value for all classes of pupils of training in the classical languages.

The king desired the discussion of what he was pleased to term more practical questions. For example: 'Was Brandenburg before the thirty years war better off or more populous than about 1740?' 'What was the influence of authors in the time of Louis XIV. upon the spirit and culture of the European nations?' The academy, however neutral it might desire to be, could not prevent its members from discussing the philosophy of Kant. Anxious as it was to be impartial, as a matter of fact not many of its members accepted the principles of Kant. They

treated them as the suggestions of a very able man indeed, but as suggestions in which men of sound mind would soon lose their interest.

In 1800, in order to meet and oppose romanticism, the theme discussed was 'Goths and Gothism.' A question which had been propounded several times without eliciting a satisfactory answer related to the advance in German metaphysics since the time of Leibniz and Wulff. The prize for the discussion of the theme which this question presented was finally divided between three men, Schwab of Stuttgart, receiving one half, Albricht of Erlangen one fourth, and another fourth going to Reinhold, the parish minister in Kiel. Although Kant wrote on this theme as early as 1791, for some reason he did not send in his paper to the academy, though some of his thoughts upon it were published by Rinkin in 1804. In one of his incomplete essays he defines metaphysics as 'the science of advancing from the knowledge acquired through the senses, by means of reason, to the supersensuous.' Such questions were also considered as 'What is the origin of all our knowledge?' 'Is there an immediate inner perception?' 'What is the relation of the faculty of the imagination to that of feeling?' 'What was the influence of Descartes upon Spinoza?' In 1796 a military man living in Kopenick left 10,000 thalers ($7,500), the interest to be given as a prize once in four years for the best treatment of some theme in speculative philosophy. In 1805 this prize was won by Franke for a treatise on analytic methods in philosophy.

Interesting themes in philology were also suggested. A prize was offered in 1794 for a satisfactory comparison of the chief languages of Europe, living or dead, in reference to wealth, regularity, strength, harmony or other advantages, the successful essay to show in what respect one language is superior to another, and which language, then existing or having existed, comes nearest perfection. The prize was won by Jenisch, a clergyman preaching in Berlin. There was great interest in the jubilee prize of 1800 which was won by Gebhard, another Berlin preacher, who sought to trace and estimate the influence which Frederick the Great had exerted on the spirit of his age, in reference to progress and freedom. In 1804 the academy asked, 'Why civilization has always proceeded from the east and has never developed originally in the west?'

The fact that no one of the treatises on ten different themes in mathematics, physics and astronomy was accounted worthy of a prize seems to show that these branches of study were not pursued in Germany to such an extent or with such thoroughness as in other European countries. The backward state of chemistry is indicated by the question for an essay, ' Has it been sufficiently demonstrated that there are only five species of elementary earths? Can these elements be transmuted into one another? If so, how is it done?' Practical matters, relating

to roads, crops, agriculture, also received attention. In 1782 Cothenius left 1,000 thalers ($750), the income of which was to be used every alternate year for a prize on some economic, agricultural or horticultural topic.

It was in an era of empiricism in philosophy, or with some enlightened thinkers, of eclecticism, in a time when the influence of romanticism was showing itself in such men as Nicolai, the originator of *Die allgemeine deutschen Bibliothek,* and in an extensively circulated Berlin monthly magazine, that Kant's critiques appeared. Empiricism quailed before them. The eclectics were startled. The academy was compelled to recognize the appearance of a new and a great thinker. Some of the more eminent philosophers in the academy, like Merian, Ancillon and Selle, brought forward what they regarded as weighty objections to Kant's positions. A few, far from sympathizing with Kant, did not fail to perceive his power and hesitated to enter the field against him, while others, like Nicolai and his friends, were hostile and ready to fight from the first. The majority in the academy distrusted the *a priori* and the *practical* reason upon which Kant laid such stress. But in spite of the determination of the philosophical element in the academy to defend empiricism, a change in feeling toward it began to show itself as early as 1800. This change was due, certainly in part, to the mental attitude of those classes in the academy which devoted thought and time to other subjects than those that were metaphysical. Such men as Hufeland, Dr. Walter,

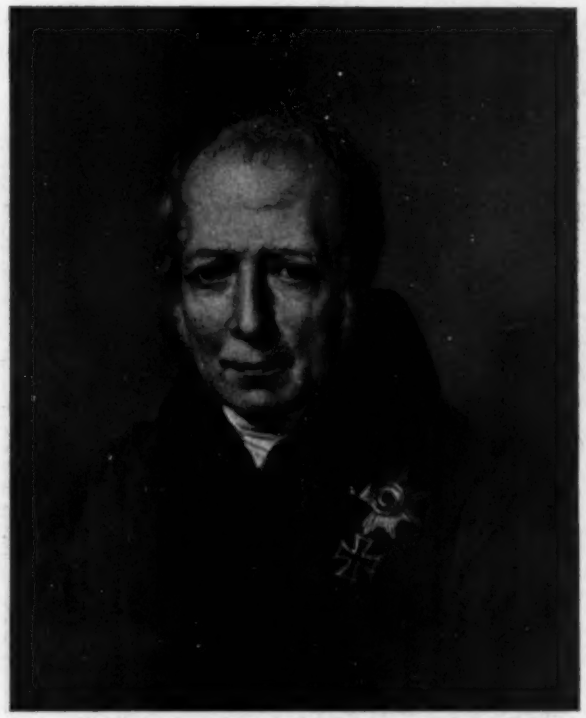
the jurist, von Klein, the statesman, director Borgstede, friends of Goethe and influenced to some extent by his spirit, as well as men like Thaer, Tralles and Johannes von Müller could not fail to be dissatisfied with the empiricism of the day, and to demand a fair hearing for any system of thought which aimed at replacing it.

The scientific regeneration of Germany followed its moral regeneration. As Harnack points out, two great streams of thought were united in nearly the same men, Fichte, Schleiermacher, F. A. Wulff, Niebuhr, von Stein and William von Humboldt. Foremost among them all

ALEXANDER VON HUMBOLDT.

was Schleiermacher, preacher, professor, philosopher. The spiritual life of the eighteenth century had been determined by its study of history and its devotion to reason. It had demanded clearness, immense learning, elegance in expression, the classicism of Cicero rather than that of Greece. French influence was everywhere felt. German authors were weakened by subserviency to forms of expression and methods of thinking suggestive of the narrowness of the schools in which they had been trained. Although Hume had little influence in Germany, the writings of Rousseau were very effective in shattering the old faith. If we also take into account the writings of Winckelmann on Grecian art,

those of Herder, Kant, Wulff, Goethe, Schiller, William von Humboldt, to say nothing of scientific treatises which were constantly appearing and indicating the discovery of new fields of knowledge to be explored, it is easy to see that nothing could prevent the incoming of an era in which the largest liberty of thought and entire freedom in investigation would be demanded for every branch of study. If at first the academy



WILHELM VON HUMBOLDT.

was somewhat conservative, it soon became a regulative force in the discoveries to which its members devoted themselves with untiring enthusiasm.

Herder's 'Philosophy of History,' a remarkable work, exerted great influence on German thought as did Wulff's writings on Homer and especially his 'Science of Antiquity.' Schleiermacher's 'Reden' or addresses to the German nobility and the educated classes of the country produced a wonderful moral and religious effect. Niebuhr imparted a new spirit to the study of history through the publication of his 'Roman History,' raising it at once to the rank of a science. Schleiermacher, recognized in the academy as the clearest thinker in its membership, impressed himself on wide circles by his translation and study of Plato, his improvement of Kant and his powerful sermons in Trinity

Church, of which he was pastor, while at the same time a professor in the university. By many he is thought to be second to no philosopher in Germany save Leibniz. As an interpreter of others' thought and in his ability to present it in new forms he had no rival. Through him Spinoza and Plato spoke directly to German scholars. But all his power was exerted in ethical and spiritual directions. Patriotic to the last degree, a lover of beauty in art and literature, deeply interested in the advancement of science, he was easily the most prominent man in Berlin, and though his energies were exercised in many fields he did not fail to direct the thought and determine the activity of the period

JOHANN GOTTLIEB FICHTE.

in which he lived. By his side and that of the noble group of men just named, should be placed Savigny, student and interpreter of law, who with Kant, Fichte and Schleiermacher introduced a new ethic into German life and gave a new character to the nineteenth century.

But this development, important and valuable as it was, was not altogether friendly to the development of purely scientific studies. The academy was chiefly interested in historical and literary, esthetic and ethical studies. At the same time it was not hostile to science. Only that did not have the first place in its thought. Nevertheless,

during the period from 1786 to 1812 it numbered thirty-two mathematicians and naturalists among its members. Gerhard, mineralogist and chemist; the elder Walter, the anatomist; Achard, the chemist, were of Frederick the Great's time. Ferber, though in the academy only a short period, was the founder of modern geognosy. Some of these men did a great deal to increase the usefulness and fame of the academy. Yet there was no mathematician in its ranks equal to Euler or Lagrange. Willdenow, nephew of Gleditsch, in charge of the botanic garden, though dying at the early age of forty-seven, carried out and improved his uncle's plans. Bursdorf laid the foundations of the science of forestry, from which Germany has received such rich returns. Though Prussia was far behind in her knowledge of chemistry, Klaproth, through the academy, did a great deal for the science by introducing correct opinions in regard to its nature and by improving the methods of its study. As an independent analytical chemist he proved to be one of the most famous chemists of his time, inferior only to Berzelius of Sweden. He discovered four new elements. Alexander von Humboldt, traveler and scientist, an author of world-wide fame, Leopold von Buch, the first geognosist of the century, and hardly less famous than Humboldt, and Buttmann, the grammarian, belong to that group of scholars, thinkers, investigators and writers who laid the foundations upon which the fame of German scholarship in the last century largely rests. The change which had taken place in the spirit and aims of the academy within the period under review, typical as it was of the change which had taken place in the universities and in the nation, was that of a generation. A new era had dawned, an era which was ready to extend a hearty welcome to new men, new methods of study and research, a new life, a new and more accurate scholarship.

THE PROGRESS OF SCIENCE.

AGRICULTURAL WORK IN THE PHILIPPINES.

THE introduction of American methods for the promotion of agriculture in the island possessions has followed closely upon American occupation. In Hawaii and Porto Rico experiment stations have been established under government support, and in the Philippine Islands a bureau of agriculture was put in operation about two years ago. The activity of this bureau in organizing its work of propaganda and investigation, as indicated by Professor F. Lamson-Scribner's second annual report, has been mainly along the lines of establishing experiment stations and farms, studying the conditions surrounding the principal agricultural industries, the introduction of farm machinery and improved methods of culture, and the testing and distribution of introduced plants and seed.

Seven experiment stations and farms have been established for special branches of agriculture or in typical sections of the country. These include a rice farm, a live stock farm, a sugar station, a farm for cocoanut and abacá (Manila hemp) culture, a testing station near Manila, and two other stations for general work in typical localities. For the coffee industry, formerly an extensive one in Batangas Province but now practically abandoned, owing to the ravages of leaf blight and borers, a coffee plantation has been started with imported hybrids, and it is hoped to secure resistance to disease and insect injuries by vigorous-growing varieties and thorough cultivation.

Special effort is being made to promote the rice industry, for although rice is the staple article of food for the Filipinos, not enough is produced for home consumption. The most approved American methods are being followed on the rice farm, and the crop of last year, which occupied about 1,000 acres, was seeded, cut and thrashed out with the latest machinery. This demonstration was a revelation to the natives whose methods of growing and handling the product are very primitive, and they were willing to pay a good toll for having their rice thrashed out by machinery, in preference to hand thrashing. In fact, the natives have taken readily to the modern agricultural implements and machinery introduced by the bureau, and soon get to use them skilfully.

On the hemp and cocoanut farm the problems of managing the plantations and of preparing copra, a staple article of export, are being taken up. A more careful selection of the species of abacá and better methods of culture would greatly increase the yield of merchantable fiber, and the perfection of a machine for stripping and cleaning the hemp fiber would aid greatly in developing this important industry. A very interesting study of the present methods of preparing the hemp, and its effect upon quality, is incorporated in the report.

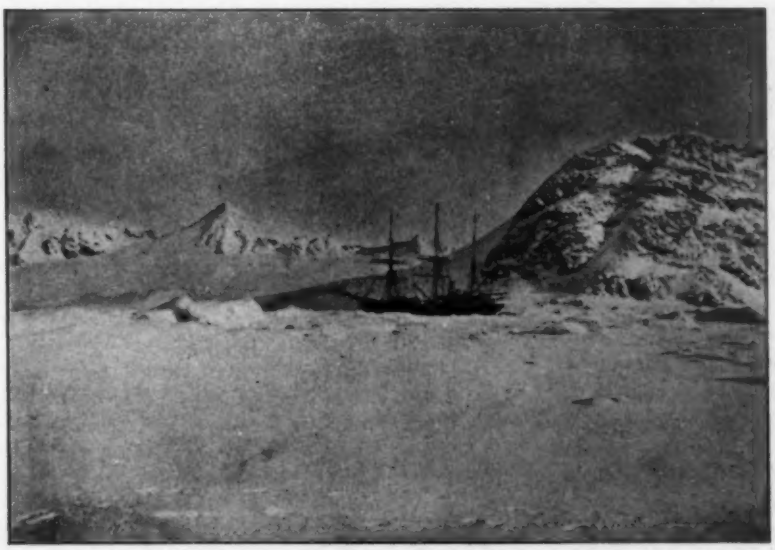
The live stock found in the islands is for the most part of an inferior quality, and the industry is at present at a low ebb, disease (surra and rinderpest) having carried off so many of the work animals as to cripple very seriously the native farming. Improved stock of different kinds has been imported for the stock farm, and the attempt will be made to ascertain the breeds and crosses best adapted to existing conditions, and to solve the forage problem. The latter is an acute

one, under present conditions, the universal forage consisting of grass cut fresh every day and sold to supply the need from day to day. Among the forage plants tested by the bureau, teosinte has given great promise, yielding enormous crops of green fodder and giving many cuttings. Nowhere in the Philippines is any attempt made to produce hay, although this is thought to be entirely practicable.

These are only a few of the more prominent lines which the bureau has already entered upon, in addition to its explorations and the publication of technical and popular bulletins, frequently in both English and Spanish. While its work has of necessity been quite largely preliminary thus far, it has clearly indicated the great opportunities which are open to it, and the value which it may be in improving and developing the underlying industry of the archipelago.

ANTARCTIC EXPLORATION.

THE safe return of the British Antarctic expedition is announced by cable from New Zealand. It appears that the relief ships sent by the British government, the *Morning* and the *Terranova*, which left Hobart on December 5, reached the *Discovery* on January 5. The ice began to break at the end of the month, assisted by systematic dynamiting. On February 12 a general break-up brought the relief ships to Hut Point, and on February 14 two heavy charges of dynamite placed the *Discovery* in open water. In the succeeding days the heavy gales drove the vessels apart and the *Discovery* was driven ashore, where she remained for eight hours in a critical position before she freed herself. During the antarctic summer Captain Scott and his party made two excursions westward over a glacier. They gained the summit on October 11 and crossed the magnetic meridian on October 20 in longitude 155½ east. Proceeding still westward, the party reached a point 270 miles from the ship in latitude 78, south longitude 146½ east. The interior of South Victoria is evidently a vast continental plateau stretching continuously upward for 9,000 feet. In November another party reached a point 160 geographical miles southeast of the



THE SCOTIA IN SCOTIA BAY.

ROUTE OF THE SCOTTISH ANTARCTIC EXPEDITION.

ship. There was no trace of land, and evidence was obtained showing that this was a vast floating ice plain.

The return of Captain Scott must be awaited for accurate accounts of the scientific work of the expedition. In the meanwhile, however, reports are being published of the results of the German, Swedish and Scottish expeditions. It will be remembered that the *Gauss*, under Professor E. von Drygalski, has returned from the exploration of Wilkes Land and the Weddell Sea, while the *Scotia*, under Mr. W. S. Bruce, and the *Antarctic*, under Dr. Otto Nordenskjöld, have been in the South Atlantic. The *Antarctic* was crushed in the ice and abandoned, but the members of the expedition and a large part of the collections were rescued by the Argentine relief ship. A full account of the work of the expedition will be found in *The Geographical Journal* for February. In the *Scottish Geographical Magazine* for the same month is an account by Mr. Bruce of the voyage of the *Scotia*, and we reproduce here an outline of the route and the position of the vessel in its winter quarters in Scotia Bay on Laurie Island. Mr. Nussman and a party of five men remain at this station engaged particularly with meteorological and magnetic observations, and the *Scotia*, with the assistance of the Argentine government, is about to return.

THE SCIENTIFIC WORK OF PROFESSOR ARRHENIUS.

THERE are many people who believe that the scientific man of to-day must be a narrow specialist if he is to make a name for himself. It may, therefore, be well to consider how far this is true of Arrhenius, to whom a Nobel prize has recently been awarded. Svante August Arrhenius was born in Sweden, February 19, 1859. In 1883 he received the doctor's degree from the University of Upsala, though not in a very satisfactory way. Arrhenius had taken for his thesis the galvanic conductivity of electrolytes, and had developed the outlines of what is now known as the electrolytic dissociation theory. The importance of the work submitted by the young Arrhenius was not perceived as clearly in Upsala then as it is now. The physicists maintained that the thesis was essentially chemical in nature and that it did not represent work in the field of physics. The chemists were equally positive that the thesis dealt more with physics than with chemistry. When this latter contention was over-ruled officially, Arrhenius was given his degree 'non sine laude.'

It is probable that the thesis would have been approved with even less enthusiasm if it had not been for Professor Pettersson, who took a strong stand in favor of Arrhenius, and yet it is not much of an exaggeration to say that the Nobel prize was awarded to Arrhenius for the ideas contained in his doctor thesis. When the theory of electrolytic dissociation was supplemented by the van't Hoff theory of osmotic pressure, the aggressive energy and wonderful teaching ability of Ostwald developed physical chemistry from an unimportant and almost unrecognized subject to its present position.

In 1886 Arrhenius received a grant from the Swedish Academy which enabled him to work in Germany with Kohlrausch, in Austria with Boltzmann, in Russia with Ostwald, and in Holland with van't Hoff. His friends, however, were not able to get him any official place until 1891, when Arrhenius was given a teaching position in physics at the Stockholm Högskola. The opposition to Arrhenius was so strong that it was with difficulty that he was promoted to the chair of physics at Stockholm in 1895, and he was only elected a member of the Swedish Academy in 1901.

During the first eight years after graduation, the work of Arrhenius was chiefly chemical. The electrolytic dissociation theory was not received enthusiastically by the majority of the physicists, and the chemists, with a few striking exceptions, were even more hostile to it. The bulk of the missionary work was done by Ostwald, but Arrhenius was not backward in the fray. While never deserting the old love, new interests arose when Arrhenius was appointed to teach physics at Stockholm. We have first a series of investigations on conductivity in flames and hot gases, which is a very natural development of the earlier work on the conductivity of solutions. This work on gases led by easy transitions to a study of cosmical physics. In 1894 Arrhenius considers the effect of the moon on the electrical state of the earth's atmosphere. In 1895 a calculation of Langley's measurements on the radiation from the moon leads to a theory of the glacial period and the Eocene period as brought about by the variation in the amount of carbonic acid in the air. In 1900 we have a cosmical speculation in which there is a systematic discussion of the nature of comets, nebulæ, protuberances, faculæ and zodiacal light, as well as of the variations of barometric pressure, terrestrial magnetism, etc.

In 1903 appeared the 'Lehrbuch der cosmischen Physik,' two large volumes of approximately five hundred pages each. The first volume deals with astronomical and geological phenomena, while the second is practically a treatise on meteorology. Arrhenius takes

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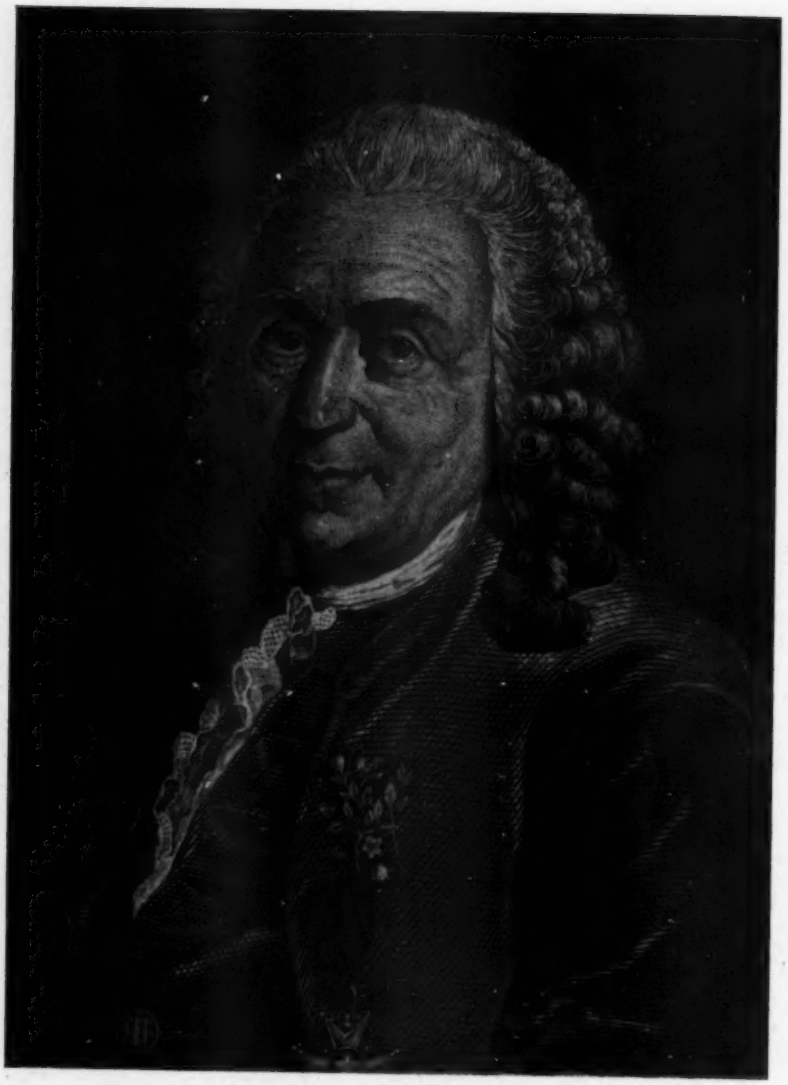
a decided stand in regard to the question of solar heat. He rejects the theories of Helmholtz and Kelvin, as being incompatible with geological evidence. While chemical theories have been considered hopelessly insufficient to account for the tremendous outpour of heat observed, Arrhenius advocates a return to them. He points out that the exchanges of energy in the redistribution of chemical equilibria are enormously greater at very high temperatures than at lower ones and that for this reason computations made from laboratory data have no bearing on the problem. While this hypothesis of Arrhenius may not stand the test of time, it is an interesting one and especially in view of the peculiar heat effects manifested by radium. Of the book itself Professor Barus says, in a review: "As a whole the work will take rank beside the great contributions of Mohn, Guldberg (who, it will be noted, shared with Arrhenius this double allegiance to chemistry and geophysics), and others, who have made meteorology a debtor to the thinkers of the North." It may also be mentioned that Arrhenius will attend the International Congress of Arts and Science at St. Louis as one of the speakers before the Section of the Sciences of the Earth.

The most recent papers of Arrhenius deal with the chemistry of serums, and it seems probable that the study of medical problems will occupy much of his time during the next few years. In Arrhenius we have a man who has received the Nobel prize before he was forty-five, and whose scientific work ranges from salt solutions to comets and from glacial periods to the typhoid bacillus. Such a record lends little support to the belief that a scientific man must be a narrow specialist if he is to attain eminence. This belief rests on a misapprehension. It is true that scientific men are accumulating facts at a tremendous rate and that this apparently makes it more and more difficult for any one man to be master of anything more than a small branch of a single science. Along with this accumulation of isolated facts, however, there comes the development of great simplifying generalizations or laws which enable men to grasp and remember an enormous number of facts. It is only during the brief periods when the discovery of new facts has not yet given rise to newer and more comprehensive theories that there is even an appearance of narrowness.

LINNÆUS.

CAROLUS LINNÆUS was born on May 13, 1707, and suggestions have already been made as to the celebration of the bicentenary of his birth. The centenary of his death was duly commemorated by the erection of a statue in Stockholm by Professor Kjelberg which stands in the Humlegarden, and represents the great naturalist holding in his hand the 'Systema Naturæ' and surrounded by allegorical figures representing botany, zoology, mineralogy and medicine. Just what form the celebration of the bicentenary of Linnæus's birth will take in his native country has not been decided, but it is not perhaps too early to make preparations for a suitable commemoration in America.

There has perhaps been in recent years a tendency to depreciate the work of Linnæus, some of his ideas having been discovered in the publications of previous writers and his works naturally containing many mistakes. But he is the founder of botany and in a way of modern natural history to an extent but rarely vouchsafed in science to a single man. He left order where there had been confusion, and largely prescribed the development of a science for a century, until the time of Darwin and the theory of evolution. Linnæus himself seems almost to have foreseen the course of events, for he said: 'A natural method is the first and last thing to be desired in botany; nature does not make leaps.'



CAROLUS LINNÆUS.

The education of Linnæus was irregular, as has been frequently the case with men of science, and his early life was more adventurous than is usual at the present day. His interest in the names and qualities of plants is said to have begun at the age of four. His father, who was a clergyman, wished to train him for the church, but when he showed no taste for routine studies, he was almost apprenticed to a shoemaker. He made his way through Swedish universities with many adventures and spent a number of years in Holland, whence he visited England. He practised medicine for a time at Stockholm, but finally received a professorship at Upsala which he held for thirty-seven years. He made this northern town the center for natural history in Europe, its students increasing from 500 to 1,500 through his influence. Expeditions proceeded thence to all parts of the world, and all discoveries were reported to Linnæus, resulting in a large series of works by him and his pupils. All honors were then showered upon him. He was ennobled under the name Carl von Linné and founded an estate. His son inherited his position at the university, but not his talents. When he died on January 10, 1778, his reputation was world-wide, and his name will always be a landmark in the history of science.

PRESIDENT ELIOT.

THE seventieth birthday of President Eliot, perhaps the greatest American now living, was celebrated at Harvard University on March 20. Mr. John Sargent has been invited to paint a portrait which will be placed in the Harvard Union. The following admirably expressed letter with some ten thousand signatures was presented to President Eliot:

March 20, 1904.

Dear Mr. President: As with undiminished power you pass the age of seventy, we greet you.

Thirty-five years ago you were called to be president of Harvard College. At the age of thirty-five you became the head of an institution whose history was long, whose traditions were firm, and whose leading counselors were of twice your age. With prophetic insight you anticipated the movements of thought and life; your face was towards the coming day. In your imagination the college was already the university.

You have upheld the old studies and uplifted the new. You have given a new definition to a liberal education. The university has become the expression of the highest intellectual forces of the present as well as of the past.

You have held from the first that teacher and student alike grow strong through freedom. Working eagerly with you and for you are men whose beliefs, whether in education or in religion, differ widely from your own, yet who know that in speaking out their beliefs they are not more loyal to themselves than to you. By your faith in a young man's use of intellectual and spiritual freedom you have given new dignity to the life of the college student.

The universities and colleges throughout the land, though some are slow to accept your principles and adopt your methods, all feel your power and recognize with gratitude your stimulating influence and your leadership.

Through you the American people have begun to see that a university is not a cloister for the recluse, but an expression of all that is best in the nation's thought and character. From Harvard University men go into every part of our national life. To Harvard University come from the common schools, through paths that have been broadened by your work, the youth who have the capacity and the will to profit by her teaching. Your influence is felt in the councils of the teachers and in the education of the youngest child.

As a son of New England you have sustained the traditions of her patriots and scholars. By precept and example you have taught that the first duty of

every citizen is to his country. In public life you have been independent and outspoken; in private life you have stood for simplicity. In the great and bewildering conflict of economic and social questions you have with clear head and firm voice spoken for the fundamental principles of democracy and the liberties of the people.

More precious to the sons of Harvard than your service as educator or citizen is your character. Your outward reserve has concealed a heart more tender than you have trusted yourself to reveal. Defeat of your cherished plans has disclosed your patience and magnanimity and your willingness to bide your time.

Fearless, just, and wise, of deep and simple faith, serene in affliction, self-restrained in success, unsuspected by any man of self interest, you command the admiration of all men and the gratitude and loyalty of the sons of Harvard.

THE WILL OF HERBERT SPENCER.

MR. SPENCER'S will is a document so interesting and characteristic that we quote some of the details, as published in the London *Times*. The first clause gives very exact directions as to the burial, and the executors are not to receive their fees unless these are observed. The clause reads: "I direct that if I shall die in any part of Great Britain, my body shall be placed in a coffin with a loose lid easily opened from below, and that it shall be subsequently burned in a proper crematory, and the ashes taken to the space numbered 33,292 purchased by me in the unconsecrated part of the Highgate Cemetery, and deposited in a fit cavity made in the concrete foundation underlying the stone slab now placed there; and my express direction is that my cremation and the subsequent deposition of my ashes shall be conducted without any species of religious ceremony such as is used either by the Church of England or any other sect, though I do not object to an address delivered by a friend; but otherwise the ceremony is to be silent, and I direct that no monument shall be placed over my ashes until at least two months after my funeral."

Among the books and manuscripts bequeathed to the trustees and executors are the 'Autobiography' with directions to secure its simultaneous publication in England and America after the corrections have been made that are marked in the press copy. The 'Autobiography' will be published in America by Messrs. D. Appleton and Co. at about the same time as this issue of the MONTHLY. Mr. David Duncan is requested to 'write a biography in one volume, of moderate size, in which shall be incorporated such biographical materials as I have thought it best not to use myself together with such selected correspondence and such unpublished papers as may seem of value, and shall include the frontispiece portrait and the profile portraits, and shall add to it a brief account of the part of my life which has passed since the date at which the autobiography concludes.' The trustees are to give their approval of the biography before it is published, and to arrange with the biographer 'for payment either of a fixed sum to be paid out of my estate or by receipt of the net proceeds of sales in England and the United States; but if the net receipts exceed £600, then the surplus to be equally divided between the biographer and my trustees, who will retain the copyright.'

The will makes numerous personal bequests, such as to Dr. Henry C. Bastian—telescope, case of drawing instruments, etc., reading easel, 'and the invalid bed of my invention with its appliances for private or public use'; to Mrs. Leonard Courtney—a victoria with india-rubber tires; to Mrs. Sidney Webb—'the piano given to me by my American friend, Mr. Andrew Carnegie,' with music-stool, music-shelves, and contained music.

The income from invested property

and from the sale of his works is to be used for the completion of the 'Descriptive Sociology.' "I declare that my trustees shall apply as nearly as possible the whole of the income derived from all investments for the time being representing my residuary estate and also the income derived by my estate from the publication and sale of the works mentioned in this my will (including the autobiography and biography) in resuming and continuing during such period as may be needed for fulfilling my express wishes, but not exceeding the lifetime of all the descendants of Queen Victoria who shall be living at my decease and of the survivors and survivor of them, and for twenty-one years after the death of such survivor, the publication of the existing parts of my 'Descriptive Sociology' and the compilation and publication of fresh parts thereof upon the plan followed in the parts already published. And I expressly empower my trustees to delegate to some competent person the duty of selecting and appointing (subject to their approval) competent compilers, deciding (subject to their approval) upon successive works to be undertaken by them, overseeing the execution of such works, superintending their approval) upon the remuneration of such compilers, and rendering periodical reports and accounts to my trustees, and out of such annual income my trustees shall appropriate and pay to the person so delegated £150 per annum, or such larger sum as, having regard to the work done, they may think reasonable and proper. And I wish that the first person so appointed shall be Henry Tedder, secretary and librarian to the Athenæum Club."

The ultimate disposition of the estate is as follows: "When the series of works, and the reorganized work, specified above shall have been completely executed and published, my trustees shall thereupon sell by auction the copyrights, stereotype plates and stock of the whole body of them, and shall sell in like manner the copyrights, stereotype plates and stock of such of my works, if any, as continue to be published by them, and shall sell in the usual way the shares, stocks, funds, securities and other property held by them as trustees, and shall give the sum realized in equal parts to the Geological Society, the Geographical Society, the Linnean Society, the Anthropological Institute, the Zoological Society, the Entomological Society, the Astronomical Society, the Mathematical Society, the Physical Society, the Chemical Society, the Royal Institution and the British Association, or such of them as shall then be in existence, and shall accept the gift upon the condition in each case that the sum received shall, within five years from the date of payment, be spent by the governing body for the purchase or enlargement of premises, or for books or apparatus, or collections, or for furniture or repairs, or for equipment, or for travelers and donations of instruments of research; but in no way or degree for purposes of endowment; and, after having previously made an authorized statement of the purposes for which the donation is to be used, the receipt or acknowledgment by the treasurer or secretary of the society to or for the benefit of which the payment is made to be in each case an absolute discharge to my trustees, and a certificate in writing signed by all my trustees stating that they have carried out the provisions of the trust to the best of their judgment and ability shall be a complete termination of their responsibilities and shall be conclusive and binding on all persons and institutions interested under this my will."

SCIENTIFIC ITEMS.

WE regret to record the death of M. F. A. Fouqué, the well-known French geologist and mineralogist; of Dr. Karl Schumann, titular professor of botany at Berlin and curator of the Royal Botanical Museum; of Henri Perrotin,

director of the Observatory at Nice; of Dr. W. W. Markownikow, professor of chemistry in the University of Moscow; of Arthur Greeley, professor of biology at Washington University, St. Louis; and of John I. Jegi, professor of psychology and physiology in the Milwaukee State Normal School.

DR. ALEXANDER AGASSIZ, director of the Harvard University Museum and president of the National Academy of Sciences, has been advanced to a foreign associate of the Paris Academy of Sciences, to fill the vacancy caused by the death of Sir George Gabriel Stokes.—McGill University has conferred the degree of LL.D. on Dr. Edward L. Trudeau of Saranac Lake, N. Y., in recognition of his work on the open-air treatment of tuberculosis, and on Mr. Edward Weston, of Newark, N. J., the investigator and inventor in electrical science.—Dr. Simon Flexner, director of the Rockefeller Institute, New York, has been elected president of the American Association of Pathologists and Bacteriologists.

PROFESSOR C. S. SHERRINGTON, of Liverpool University, opened his course of Silliman lectures at Yale University on April 22.—The subjects of the Herter lectures given during April at the Johns Hopkins University by Professor Paul Ehrlich were: (1) 'The mutual relations between toxine and antitoxine'; (2) 'Physical chemistry versus biology in the doctrines of immunity'; (3) 'Cytotoxines and cytotoxic immunity.'

THE new medical laboratories of the University of Pennsylvania will be dedicated on June 11. The laboratories cost $700,000. The principal addresses will be delivered by Dr. H. P. Bowditch, professor of physiology at the Harvard Medical School; Dr. R. H. Chittenden, director of the Sheffield Scientific School, Yale University; Dr. George Dock, professor of medicine at the University of Michigan, and Dr. Horatio C. Wood, professor of materia medica and pharmacy at the University of Pennsylvania.—Active preparations are being made at the New York Zoological Garden in Bronx Park for taking the animals out of winter quarters. Work is also being pushed with all possible speed on several new houses in the garden, the most important of which are the bird house, to cost $115,000; the small mammal house, to cost $38,000, and the ostrich house, to cost about the same sum.—The executive committee of the Carnegie Institution has adopted the recommendation of the biological committee to establish a Department of Experimental Biology and to call Professor C. B. Davenport, of the University of Chicago, to the charge of it. The work of the department will include at present, among others, a station for Experimental Evolution at Cold Spring Harbor, Long Island, on land granted by the Wawepex Society, and a Tropical Marine Biological Station at the Dry Tortugas. Dr. Davenport is proposed as director of the former station and Dr. Alfred G. Mayer, of the Museum of the Brooklyn Institute of Arts and Sciences, as director of the latter station. Fuller details are promised as the plans of the department progress.